REFERENCE BOOK SHEET
PRODUCT ENGINEERING

PRODUCT ENGINEERING

NOVEMBER, 1942

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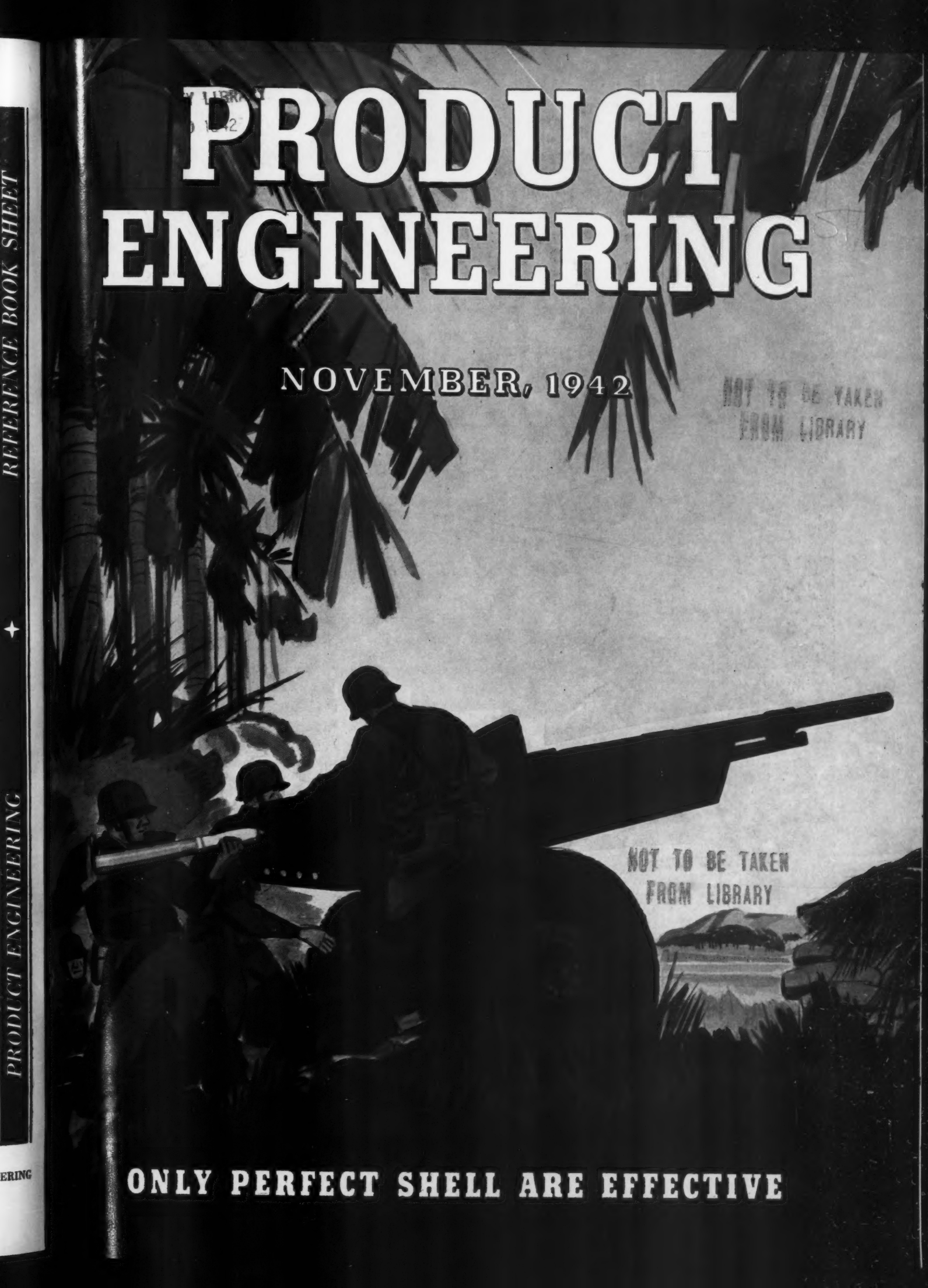

ONLY PERFECT SHELL ARE EFFECTIVE

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SCRAP iron or steel turnings, clippings, short ends, worn out or broken tools, spoiled work, idle and obsolete machinery, etc., are valuable as raw materials for remelting in the production of new steel.

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To be of maximum immediate assistance, scrap should be segregated by composition wherever possible. Turnings, spoiled work etc. should be identified (SAE, AISI, NE etc. grade number) at the machine where they are generated and so handled as to avoid contamination by waste material or scrap of other types and grades.

The metallurgical experience of our staff is available to aid you in technical phases of metal salvage.

KEEP SCRAP MOVING INTO WAR PRODUCTION!

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK, N. Y.

PRODUCT ENGINEERING

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The "Why's" of Shell Design

"Praise the Lord and pass the ammunition!" That epic remark by a navy chaplain speaks volumes. But what would happen if in the design of that ammunition the crimping groove had been made a little different, if tolerances had been increased, or the taper at the base was wrong, or any one of a dozen more different items, insignificant to a layman, had been altered? Why shell must meet the specifications and what happens if they don't is explained on pages 620 to 623.

Watch Electronics

Behind the curtain of Army-Navy secrecy, electronics is starring in many amazing performances in the control of war machinery. But there's another electronics show going on out in front of the curtain—on the machine tool stage. One of the latest tricks brought to our attention is Plan-O-Mill Corporation's Model 3 planetary milling machine, with a tough speed control problem solved simply, economically and efficiently by a few quiet electron tubes. Complete description on pages 626-628.

Hydraulic Control and Power

Whether you are designing hydraulic systems for aircraft or just want to know what advantages there would be in using a pump, a valve, a cylinder and a few feet of pipe to perform a simple push and pull operation, you will want to read "Aircraft Hydraulic Control and Power Systems," page 656. This article is the first in a series describing the use of hydraulics in airplanes.

Easy Standardizing

Engineers and scientists are indebted for preferred numbers to a Col. Renard, of the French Army, who was unimpressed with the idea of abiding by 425 different specifications for captive balloon mooring cables. Seventy years later, John Gaillard turns up with the Prefernograph, a device facilitating the

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PRODUCT ENGINEERING. Published monthly. Price 50c per copy. Allow at least ten days for change of address. Communications about subscriptions should be addressed to Director of Circulation, PRODUCT ENGINEERING, 330 W. 42nd St., New York. Subscription rates: United States, Canada, Mexico, Central and South American countries, $5 for one year, $8 for two years, $10 for three years. Great Britain and British Possessions 36 shillings for one year, 72 shillings for three years. All other countries $6 for one year, $12 for three years. Entered as second-class matter August 21, 1936, at Post Office, Albany, N. Y., under the act of March 3, 1879. Printed in U. S. A. Cable Address: "McGrawhill, New York." Member A.B.P. Member A.B.C. Copyright 1942 by McGraw-Hill Publishing Co., Inc., James H. McGraw, Founder and Honorary Chairman; James H. McGraw, Jr., President; Howard Ehrlich, Executive Vice-Chairman; Mason Britton, Vice-President; B. R. Putnam, Treasurer; Joseph A. Gerardi, Secretary; J. E. Blackburn, Jr., Circulation Manager, Publication Office: 99-129 North Broadway, Albany, N. Y. EDITORIAL AND EXECUTIVE OFFICES: 330 W. 42nd St., NEW YORK. Branch Offices: 520 N. Michigan Ave., Chicago; 68 Post St., San Francisco; Aldwych House, Aldwych, London, W. C. 2; Washington; Philadelphia; Cleveland; Detroit; St. Louis; Boston; Atlanta, Ga.

use of preferred numbers. For information on how these devices can simplify the process of standardizing production, see Mr. Gaillard's article on pages 665 to 667.

Models and Analogues

Mechanical problems which involve the interchange and dissipation of energy are very similar to those encountered in electrical circuits. If a mechanical problem can be reduced to an equivalent electrical circuit, it may be possible to obtain a complete solution in short time with a model circuit and a cathode ray oscillograph. E. N. Kemler tells how in his article "Models and Analogues for Solving Design Problems," page 660.

Forgings Cost Predictor

For the use of their own design engineers, Douglas Aircraft Company made a close study of the cost of forgings, and worked up charts and tables by which a designer can predict with reasonable accuracy the cost per piece of a tentative forging design. Although variations in geographic locality, labor costs, relationships with the forge shop, etc., prevent the acceptance of these figures as a cost "bible" for all industries, the data can be very useful in comparing relative costs of different designs and in comparing costs with those of stampings, castings, and other fabrication methods. Turn to page 641.

Gate Shear Loads

Designed to aid in determining the cutting loads in gate shears, two nomographic charts solve formulas for cutters having a tapering blade, and for cutting loads when the metal is at different temperatures. Considerable effort is saved in computing loads for tapered knives because of fractional exponents in the formula. This month's Reference Book Sheets, pages 677 and 678, were prepared by J. P. Doolan.

Spring Design Made Easier

It is logical to design the spring first, and then build the machine around it, but frequently the process is reversed. Determination of characteristics early in the design is made easy by the rapid and direct "cookbook" procedure beginning on page 662. You'll find the gatefold chart handy. Author is Carl Thumin of General Electric Company.

Another Sherman Act

Business men whose operations are based on patents stand to acquire an imposing partner—none other than Uncle Sam—if the Lucas bill, which is a personally-dictated summary of Thurman Arnold's views on patent regulation, becomes law. This bill would make the Justice Department's anti-trust division the agency which business men would have to consult to determine whether they were using their patents within or without the law, would have the veto power with which to ban any activities it did not like. Read all about it on page 644.

More Relay Hook-Ups

Concluding the table of relays and control devices, started in the October issue with devices for preventing overload and overheating on a.c. and d.c. motors and control circuits, this month's table includes devices suited for other types of protection, such as preventing over- and under-voltage, open or shorted field circuits, holding constant polarity and frequency, maintaining power factor. Turn to page 647.

Tolerances vs. Quality

Any engineer who has ever wrestled with the dilemma of setting up tolerances on machined parts so that they will satisfy both the purchaser's specifications and the demands of the production department for workable limits, will appreciate the article "Dimensional Tolerances and Quality Control," on pages 634-636 of this issue. Author is J. W. White, director of engineering, Hydraulic Division, Bendix Aviation.

Surface Roughness Control

Aimed at clarifying surface roughness designations of machined or ground surfaces for the aircraft industry, a new aircraft standard has been issued. Described for PRODUCT ENGINEERING readers by Vega's John W. Borgquist, the new system enables control of roughness limits by actual measurement. Turn to page 638 for full details.

Photostat-Tracings

Large engineering departments that are alert to the time-saving possibilities of photographic methods which eliminate much routine drafting work will find much of interest in this month's article on Photostat Tracings. Mr. Lester C. Jones outlines the procedures, advantages and limitations of a photostat method used at the Lockheed Aircraft Corporation. For more information, turn to page 653.

Stresses in Aluminum Rings

Derivations of stresses produced by a steel bushing pressed into a hole in an aluminum fitting are presented on page 659 by Alcoa's H. N. Hill. These equations, set up for idealized conditions, are applicable within the elastic range of aluminum. They give the radial pressure between bushing and ring, and the maximum stresses.

PRODUCT ENGINEERING

WHAT'S COMING

Expediting Design Changes

If you have an idea for speeding production or saving strategic materials in war products that you are designing or producing, by all means take steps to put that idea into effect immediately. The big problem, of course, is to obtain the approval of Army and Navy, who have to be mighty careful what they give the boys to fight with. Army and Navy, however, are extremely anxious to corral all the ideas, and they are geared to move fast on the good ones. In an early issue PRODUCT ENGINEERING will show you the best and quickest ways to obtain Army or Navy approval of design changes.

Deep Drawn Shapes at Low Cost

Many streamlined machine tools now being produced owe their attractive appearance to heavy steel stampings which take the place of cast iron doors, cover plates, guards. Other design advantages of the stampings are light weight, less material required, and use of welded fabrication. Cost is low, too, if the heavy steel shapes are well designed. How to do this will be shown next month in an article by Edward H. Hautz.

Open-Shell Structures

The rapid growth and development of aircraft have introduced many complicated problems in the design of structures. Of interest to all designers of transportation equipment are procedures for determining the stresses in skin structures and their load carrying capacity. The December number of PRODUCT ENGINEERING will present the first of a series of articles by E. H. Spaulding of Lockheed Aircraft covering torsion analysis of open shell structures restrained against warping.

Electronics—Secret Weapon of War

Presager of a New Scientific and Industrial Era

THE END of World War I left scientists with a new plaything. They did not know it at the time but they had their hands on a revolution. Within two years the world had radio broadcasting. Within ten years the whole art of motion pictures had been transformed as talking pictures replaced silent movies. Within twenty years television was born and people were seeing pictures in motion by radio.

The fulcrum of this revolution is the electron tube, a new tool of illimitable possibilities. One form of the electron tube is the familiar radio tube; the much publicized electric eye is another. There are many other forms, each having distinct capacities for saving time, saving energy, saving money, protecting life, limb and property.

The electron tube puts the electron to work—and the electron is the basic building-block of the universe.

Electronics is the new art, the new science of putting the electron to work. Radio and sound pictures and television are aspects of electronics; but there are many other facets of this revolution which have been brewing since the last war.

The electron tube has a typical American family tree. Edison made the basic discovery of the "Edison effect" some sixty years ago. This was followed by the invention of the "Fleming valve" and the "de Forest grid". Then Armstrong contributed his share, and hundreds of engineers in garret and cellar workshops and in the great university and industrial laboratories went to work on the tubes which employ electrons. The tube was a plaything before the last war but the world conflict brought it out of the toy stage and made it a practical, powerful tool.

Today the electron tube is guiding the destinies of the greatest armies and fleets ever engaged in the history of the world.

It is a part of the nerve center of the battleship, directing its course, finding its adversaries, broadcasting running accounts of air battles to its crews, directing gun fire and determining ocean depth.

In the air it is the means of locating and identifying enemy planes, piloting planes automatically, giving communication from plane to plane and to shore. It is even operating the controls of the plane.

In the maneuvering tank, in the officer's car, on the back of a foot soldier it transmits and receives vocal messages from every unit of the fighting forces.

Along our borders, and those of our Allies is an electronic screen which counts, follows and identifies enemy planes a hundred miles away through darkness and through fog.

In industrial plants there are electronic counters that enumerate passing articles faster than the eye can see; automatic sorters which discard defective, oversize, undersize, off-color articles; automatic cutters; devices which inspect the inside of things which the eye cannot see; controls which protect workers; controls of temperature; smoke eliminators; intruder alarms; automatic controls for whole batteries of machines.

In its October progress report on American industry, the War Production Board points out that the radio business is five times greater than a year ago. From 20 million dollars a month last fall, it has increased to well over 100 million dollars a month. Unfilled war orders are in excess of 4 billion dollars.

From such vast growth will emerge a new engineering of products which will immeasurably improve our peace-time living.

After the war broadcasting will be infinitely more satisfactory: radio receivers will perform with a new fidelity which will amaze us. Television reception will be as flawless as the motion picture. Present secret war developments will readily be convertible to peace-time devices that will improve our standard of living.

No longer will ships collide with other ships, with icebergs or the shore. No longer will trains collide and aircraft crash in flight.

Garage doors will open as we approach and automatically close themselves. Electric lights will automatically go on and off according to our wants and needs. Furnaces and boilers will be controlled and smokestacks will cease to belch wasteful smoke. Air will be made dust free and germ free. Food contamination will be checked, meat made tender.

Grade crossings will be made safe and auto traffic will be automatically controlled.

Medical science sees new wonders ahead. Already it is possible to see "whiskers" on germs, germs which heretofore had been but a blur when viewed through the strongest optical equipment available.

Today so much secret development is going on in the ultra-high-frequency field that little can be said of its great future. But, without divulging military secrets, it can be said that ply-wood is being dried electronically in minutes instead of hours. Ultra-high-frequency welding (not to be confused with flame welding controlled electronically) is being done dramatically and efficiently.

Ultra-high-frequency heating promises to revolutionize the baking industry—it may even heat our homes.

What is this miracle working tube that can see, hear, taste, feel and smell a thousand times more sensitively than was possible heretofore?

What is the electron? No one knows, not even the scientists who know how to employ it. Electrons cannot be seen or felt; but if 6¼ million million million electrons are pushed through a 100-watt electric lamp per second, it will light up to full brilliance. For electric current merely is a mass movement of electrons. Each electron carries its share of electricity, and since the electron has so little weight it can be moved easily and quickly. Therefore, electricity transported by electrons can be turned on or off with great ease and speed. The electron tube merely is a device that controls the flow of electricity. It is an amplifier of power which can be made to do wondrous things. The sound of a termite gnawing inside of a log can be amplified a million times . . . to a roar that can be heard over great distances.

Colors can be classified and matched to a degree not possible by any other means.

Chemical or vitamin consistency can be recognized by counting radio activity within the subject being analyzed.

There is no industry in which electronic circuits cannot be used to speed up production, to increase accuracy, to do heretofore impossible tasks of calibration and measuring.

The opportunities afforded the engineers who are developing this new "electronic age" are limitless.

* * * *

Today the electronic industry is 100% at war. It is meeting the exacting demands made upon it.

Never before was electronic equipment called upon to withstand temperatures ranging from 75 degrees below to 150 degrees above zero Fahrenheit. Never before did radios and transmitters have to withstand the shaking and abuse to which they are being subjected today.

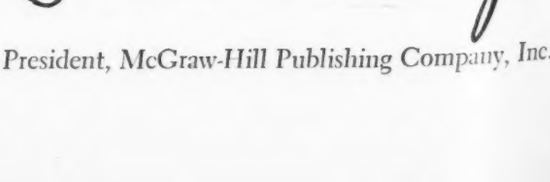
War demands have called for much redesign, much change of materials and a new conception of operating to tolerances never dreamed of in peace-time material. As a result, electronic parts and equipment makers are building better devices.

Universities and colleges are working at top speed to produce electronic engineers, for every radio operator in a plane, every radio man in the ground forces and on ships, every man operating radar equipment or electronic control devices in ordnance . . . and there are many thousands of them . . . must be a trained technician.

The wall of military censorship is high but it is no secret that one of Britain's best weapons that keeps the Luftwaffe from exterminating London is a radio locator, a device that gives alarm of approaching planes long before they can be seen with telescopes. Scanning the horizon constantly the locator warns of the enemy's approach. In the nose of a night fighter, the locator informs pilot and gunner when the enemy is within range. Neither is it a military secret that gunfire can be controlled by electronics, and that electronics is having a big share in training our new armies.

Necessity draws a veil over the most dramatic uses of electronics in warfare, but among those who know there is nothing secret about the fact that many of today's wartime applications will revolutionize our peace-time lives. Electronics will invade every industry with totally new devices and machines. The future of the electronics industry is limited only by man's imagination.

Such is electronics, and its destiny!



President, McGraw-Hill Publishing Company, Inc.

This is the sixth of a series of editorials appearing monthly in all McGraw-Hill publications, reaching more than one and one-half million readers, and in daily newspapers in New York, Chicago and Washington, D. C. They are dedicated to the purpose of telling the part that each industry is playing in the war effort and of informing the public on the magnificent war-production accomplishments of America's industries.

PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

Planning for the Post-War Period

DESIGN ENGINEERS agree that this is not the time to make detailed plans of products for post-war consumption. There is little or no time now for such activity, and if there were, it is impossible to design intelligently for production at an unspecified, future date. There will be appreciable changes in material prices before production can begin for post-war use. Scientific discoveries, new design techniques and improved production methods would render today's designs obsolete before the war ends.

This does not mean, however, that design engineers should close their minds to post-war planning. Actually, many design executives are thinking and planning seriously for the day when peace shall reign again. When that day comes, the same engineering thought and ingenuity that developed today's deadlier swords will be applied to tomorrow's better plowshares.

Simple as it may sound, it will not be easy to adjust engineering thought from wartime to peacetime standards. This is particularly true of the present war because of the tremendous technological advances which are being made in the fields of materials and production. Furthermore, the materials shortages which have arisen from our furious drive for full war production and the substitutes which have been developed to meet them have forced designers to broaden their knowledge of the possibilities of all materials. Over the past two years, designers have developed considerable "know-how" regarding what they can do with various materials.

All these considerations add up to the realization that design possibilities today are many times greater than they were before the war. They will be many times greater at the end of the war than they are now. It will be no easy matter for the post-war designer to choose the best possible way of doing a given job.

It goes without saying that experience gained from the design of wartime products will be applied to improved peacetime goods. Of particular significance in this connection are the high standards to which the war has accustomed many designers. Automobile manufacturers have learned from producing aircraft engines that the thousandth-in. tolerances to which they formerly worked can be lowered to ten-thousandth-in. tolerances without appreciable cost increases. Undoubtedly, many other industries converted to war production of such high-precision articles as shell fuses and instruments have learned the same lesson and are thinking of their post-war production in terms of finer finishes and more accurate dimensions.

These, then, are the factors which compose today's post-war design activity. Engineers are not making black and white drawings of what they hope to sell when peace returns, nor will the exigencies of national defense permit the energies of trained designers assigned to military equipment to be diverted.

This is not the time to put post-war designs on paper. It is the time, however, to build a fund of data and information which will enable the designer to be alert to the vast possibilities of his post-war job. It is the only way he will be able to accomplish the task of post war designs without false starts and wasted time.

WARTIME DESIGN NEWS

HOLDUP AT HOME

The United States war team opened its fall campaign with the military and naval blockers opening holes at each end of the Pacific while the Washington ball carriers huddled over strategy of the home front.

Materials supply and manpower were the principal problems at home, and neither problem was being solved at the rate the military was pushing ahead.

The former was cluttered up with advices which saw the Production Requirements Plan buried under the weight of its own red tape, but which agreed unanimously that it will function for one or two quarters next year, a period whose production will be vital to the United Nations.

Manpower control was assuming the proportions of a domestic second front, with such government men as Paul V. McNutt, of the War Manpower Commission, holding it to be vital, while labor eyed it with deadly distrust.

Elsewhere, the War Production Board established a Smaller War Plants division, ostensibly to spur war production in as many plants as possible. It was followed only days later with a proposal by WPB Chief Donald M. Nelson to establish a War Liabilities Adjustment Agency to aid small firms faced with shutdown because of the materials situation. Some observers saw it as the executioner to carry out the disposal of non-essential industries which can not be allowed to complicate further the already-tight materials situation.

MATERIALS MANAGEMENT

PRP was just beginning to do the job for which it was designed. Its ratings, although issued a month late, did scale down requirements to the available supply, and as a result, fourth-quarter certificates, and those issued next year, are expected to produce the materials they call for. However, one real weakness of PRP was developed. It became obvious that some parts producers were being cut down by different percentages than the assemblers for whom they produced.

The materials distribution plan coming up, which is expected to get into operation during the second quarter of 1943, is the pet of Ernest Kanzler, new WPB director general for operations. Kanzler won for his scheme the approval of Ferdinand Eberstadt, new WPB vice-chairman in charge of materials distribution. Essentially, the plan will operate thus:

Armed forces will prepare month-by-month schedules of the finished products they except. Big prime contractors will prepare corresponding schedules for their sub-contractors and suppliers, and will furnish bills of material to meet these schedules. Then WPB will pare all schedules to meet available supplies of materials, and war contractors can buy what they need to meet the approved schedules.

This method will aid in the achievement of the "balanced" production called for recently by Nelson, for under it, WPB will be able to allot extra supplies to lines it wants developed and to withhold them from over-expanded operations.

Looking well ahead of current supply shortages, Dr. Charles M. A. Stine, vice-president of E. I. DuPont de Nemours, told the American Chemical Society that developments forced by the war might have taken half a century to realize under less stringent conditions. As an example, he cited the vastly-increased aluminum production capacity, which, he said, will furnish enough metal in one year to build three times the number of passenger cars now operating on American railroads. From 10 to 100 times as many industrial chemicals will be available as before the war, Dr. Stine predicted.

MANPOWER CONTROL?

Some predictions on the manpower situation go so far as to picture government inspectors in every plant, pruning payrolls to the last possible worker, checking on the efficiency of the labor force and guarding against the wasting or hoarding or labor. Union men as well as management men may be found in such jobs, and the right to hire and fire may well be abrogated. Individuals will feel the pinch as much as management under this prediction, with workers bound to their jobs at fixed salaries, their real income regulated by rationing and their surplus funds tapped by taxes, compulsory savings, war bonds and increased prices.

An indication of how far the problem has advanced may be seen in the fact that the National Service Bill, pending for a long time but pigeon-holed by the election and by differences within the administration, is showing signs of life. Biggest question is whether to do the job through the existing Selective Service organization or through the War Manpower Commission and its myriads of sub-divisions, including the U. S. Employment Service.

Production and labor officials raised a clamor for a reasonably stable determination of how many men the military services will need. Their answer was a pointed question by Brig. Gen. Lewis B. Hershey, national draft chief, who asked the basis on which the services could make such an estimate with events on the fighting fronts so fluid. He then told management that it must "look itself over objectively" and decide how many men it needed, and then "probably cut that figure in two."

ELSEWHERE ON THE MANPOWER FRONT:

President Roosevelt banned payment of "penalty overtime" by ruling that no employee need be paid double time for Sunday work unles it was the seventh consecutive day on the job. Otherwise, no more than time and a half shall be paid for work over eight hours in any day or 40 hours in any week.

McNutt told an advisory group that four-fifths of all war jobs can be performed by women, and added that 5,000,000 women must be added to the nation's labor force by the end of 1943.

The task of writing the administration's manpower draft act went to Arthur S. Flemming, U. S. Civil Service Commissioner, who must make his peace with administration advisors who want to do the job through Selective Service, and Paul McNutt, whose attorneys have a bill which lets the Employment Service run the show.

SUPPLY SITUATION

With much of the nation's energy concentrated on an intensive drive to round up 17,000,000 tons of metal scrap to keep steel mills operating at capacity until spring, steel, the one war need which the United States seemed to have in ridiculous abundance, continued to be a prime materials headache.

WPB announced that 75 percent of the nation's monthly finished steel output is going into direct war use, the remainder into such essential uses as railroads and machine manufacture. Tanks, guns and ships chew up much of the steel allocated to direct war use.

The way was opened for some steel savings by revising specifications for reinforcing steel. New specifications require use of larger structural members and higher unit tensile stresses, thus saving on the amount of steel required. The order, issued by WPB, covers all buildings constructed, financed or approved by federal agencies on contracts placed after December 4.

Free silver went to war when the Treasury announced that all its supply in excess of currency requirements, estimated at 5,000,000 ounces, has been loaned or promised to war industries. Current demands for essential use alone now absorb all imported silver and by early 1943 are expected to absorb all newly-mined domestic silver as well. Biggest use for the metal is in brazing alloys or as a substitute for tin in solder and aircraft engine bearings.

Cryolite was put under complete allocation and use control late in September, and may neither be delivered, received nor used in its natural or synthetic state except on specific WPB authorization.

PRODUCTS

WPB orders ran the gamut from embossed identifications on steel shipping drums to machine tools. For instance:

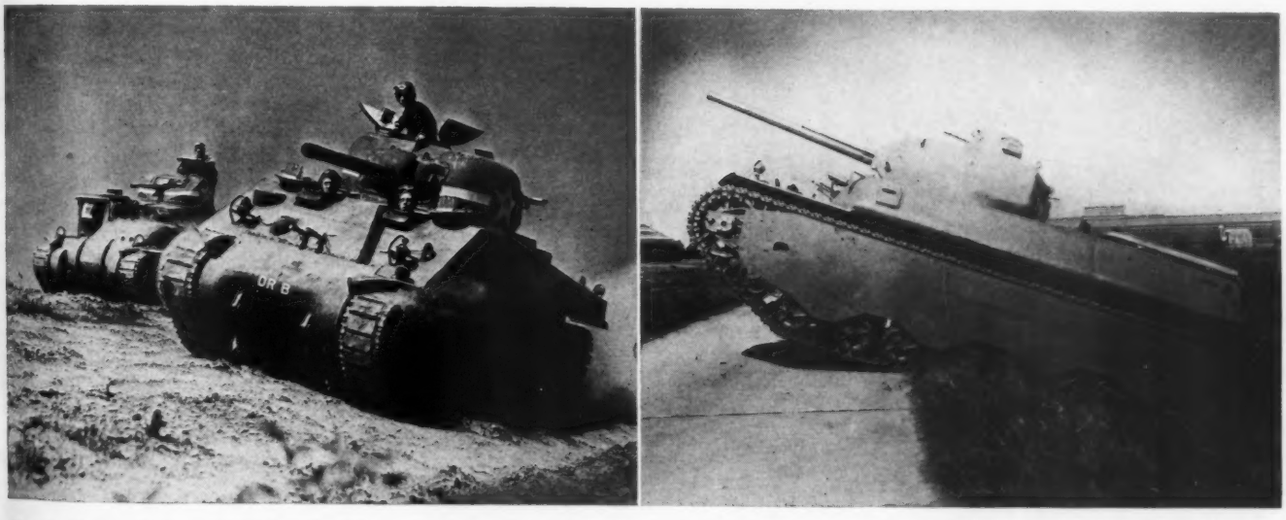
No electronic devices may be manufactured in excess of minimum inventories to satisfy orders rated A-3 or higher. No more than a 45-day supply of 12½ percent of 1941 sales may be had in stock at any time.

Approximately 200 food, chemical and petroleum products may not be packed in new or used steel drums after November 14, nor may an additional 35 items be packed in a new or used drum purchased, manufactured or delivered after September 14.

Saws, axes, hatchets, adzes and light hammers came under the list of hand tools for which simplified specifications have been ordered. Hand shovels, spades, scoops and telegraph spoons were simplified in July. Hatchets, broad and forged axes, forged adzes and forged light hammers may not be produced except to simplified specifications after November 18, and producers may not put ferrous metals into productions for tools except those conforming to simplified specifications after November 2. Production of all unsimplified saws stops December 18, and no steel may be processed for them after October 18. Saw specifications were cut from 800 to 210. Those affected by the order include 10 types of manually-operated wood and special-purpose tools. Varieties of axes were reduced from 382 to 147; hatchets from 62 to 38; broad axes from 12 to 5; adzes from 11 to 9 and hammers from 180 to 113.

COMMITTEE MAPS OTD SCOPE

A nine-man committee is at work on a program defining the scope, functions and operational methods of the proposed Office of Technical Development, planned by the War Production Board, PRODUCT ENGINEERING, September (page 513). Dr. Webster N. Jones, director of the College of Engineering, Carnegie Institute of Technology, Pittsburgh, is chairman of the "policy" committee. Other members are S. D. Kirkpatrick, editor of *Chemical and Metallurgical Engineering*, a McGraw-Hill publication; Dr. Lawrence W. Bass, research director of the New England



Evolution of army tanks is strikingly shown here with an M-3, General Grant, an M-4 General Lee and a new heavy tank converging from left to right. Notice how the armament grows progressively heavier. The M-3 carries a reasonably small turret cannon and probably several light machine guns. The M-4, to its right, carries a distinctly heavier turret cannon and three visible machine guns. Both of these are 30-ton tanks, with the M-4 at least bearing a welded hull and a revolving turret which allows it to concentrate fire from its cannon in any direction. Production figures for the M-4 may not be disclosed, but they are "substantial."

The heavy tank shown to the right, the first completed, was finished some time ago. It weighs about 60 tons, but is not twice the size of the M-3 and M-4 models. It carries a heavy turret gun, the caliber of which may not be published but which has a longer range than a field gun. Beside the turret rifle is a 37 mm. cannon, probably the size of the main turret gun of the M-3. Both guns can be elevated for anti-aircraft use. Atop the cannon is a heavy machine gun, and beneath them are three more, the calibers of which may not be disclosed. Construction of the hull is rivetless cast steel. The track is protected.

Industrial Research Foundation, Boston; Dr. Oliver E. Buckley, president of the Bell Telephone Laboratories, New York; Col. Clarence E. Davies, Army Ordnance Department, Washington; Dr. Ray P. Dinsmore, development department manager, Goodyear Tire and Rubber Company, Akron; Admiral J. A. Furer, U. S. N., Washington; Dr. Jerome C. Hunsaker, head of the departments of Mechanical and Aeronautical Engineering, Massachusetts Institute of Technology, Cambridge; and H. W. Graham, metallurgy and research director for Jones and Laughlin Steel Corporation, Pittsburgh.

Plane Design Is Compromise House Committee Decides

The House Military Affairs Committee summed up its investigations of the nation's military aircraft with a conclusion fundamental to every designer —that every design is a bundle of compromises.

The two-weeks-long probe followed widespread speculation and discussion as to the real value of the ever-growing fleet of fighting planes turned out in the United States. Even our pilots were concerned.

Gist of the committee's findings was the elementary knowledge that you can design a plane to fly like a bird or to fight like a tiger, but that so far, no one has put into combat operations a plane which can do both in every sense of the word.

Light guns and radio equipment, little or no armor, small fuel and ammunition supplies enable the Japanese Zero fighters to flit around our P-40's with ease, but the score is evened when the more cumbersome P-40's cut loose on the flimsy Zeros with jack-hammer blows delivered by a well-protected pilot. Without being too specific about it, the Army gives its word that when our planes meet the enemy we win consistently by wide margins.

Experts put us in the hole on high-altitude fighters, which we do not yet have in quantity production. Low and mid-altitude fighters such as the P-40 and P-39, and the Navy's Grumman fighter, are vicious opponents in their realms, but the P-38 and P-47 Army ships and the Navy's F4U are just showing—and late.

In the latter two types, the United States abandons liquid cooling for maximum engine performance, at least temporarily, and another milestone in the air-cooled-liquid-cooled controversy goes into the record. Each ship is powered with a 2,000-hp. air-cooled engine. The P-38 flies alongside them only because it has two engines, and it will never maneuver comparably to a single-engine plane.

The Army's low-level ships are liquid-cooled and develop about 1,350 hp. Efforts to get 2,000 hp. out of such engines have not proved successful, and the switch was necessary to keep up with the enemy. Experts point out that the switch does not necessarily doom the liquid-cooled power plant, but with the time for speculation and argument past, the need now is for actual, not expected or theoretical performance.

Aircraft Industry Fears Talent Raid by Kaiser

The letter of intent—covering three sample planes — which Shipbuilder Henry J. Kaiser took back to the West Coast in lieu of a contract for 5,000 cargo aircraft is still a cause of unhappiness among top men of the aviation industry. Those who know estimate that it will require the services of 1,000 engineers to develop the plans for the three flying boats, and the industry can see no other source of supply for those engineers than itself.

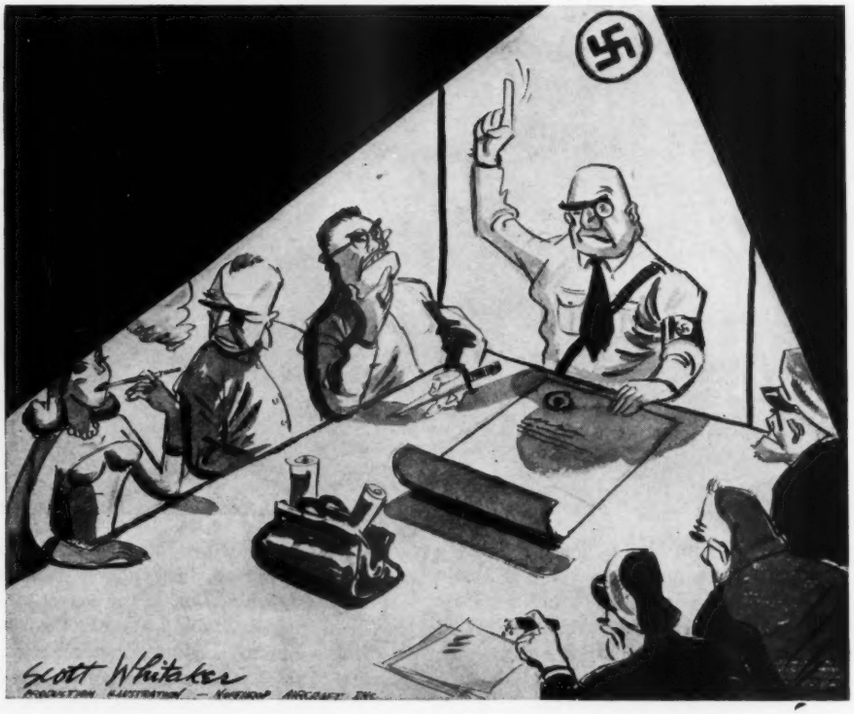
Kaiser's need will be there despite the fact that the industry currently needs all possible manpower to keep abreast of the trends, to make the changes which are flowing back from the battlefronts and to keep on top of the Axis aloft.

It's not that the plane builders envy Kaiser the business, for they are convinced that he will never show them up on production, and the day when he might be cramping their material-supply sources seriously is still well in the future. Even if he gets a mass-production order, Kaiser probably will be competing seriously only for engines, for his planes are expected to consist principally of wood.

Insiders feel that Kaiser continues on the shaky ground he trod upon in the assumption that the government wanted a truly gigantic air cargo fleet.

Our current cargo plane program stands at 30 percent of multi-engine output, the level at which the high command wants it, being yet unwilling to put surface-ship cargo into the air on a grand scale.

The possibility that Kaiser's operations may yet be stopped before he reaches the mass-production stage 25 months hence still exists. Observers point out that the vastly-bigger Higgins shipbuilding program was cut short and add this to the belief that the WPB and the War Department never wanted to give Kaiser a contract and were only forced into granting the relatively nebulous letter of intent through the pressure of public opinion.



"Proceed to America and STOP Standardization of Parts!!!"

Cartoon by Scott Whitaker, Northrop Aircraft Inc. Available through arrangement with the National Aircraft Standard Committee, Aeronautical Chamber of Commerce of America, Shoreham Bldg., Washington, D. C.

WAR MATÉRIEL

Design • Developments

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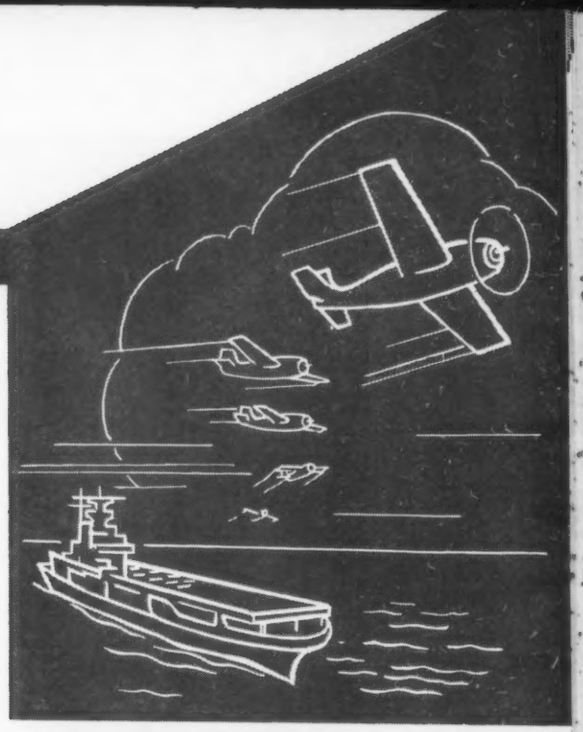
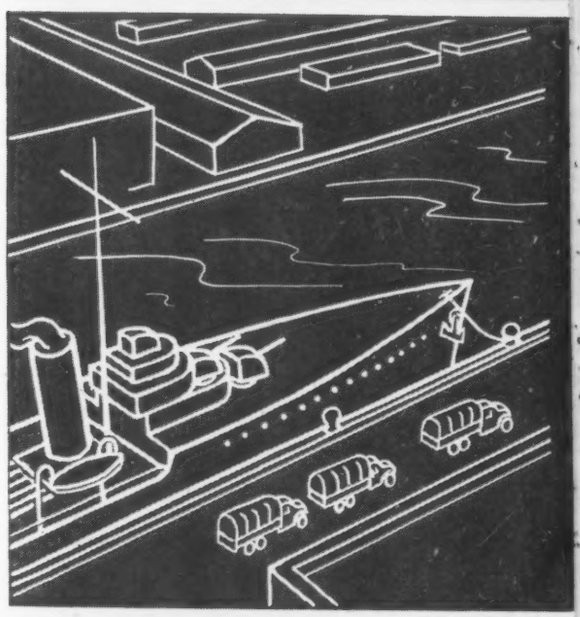
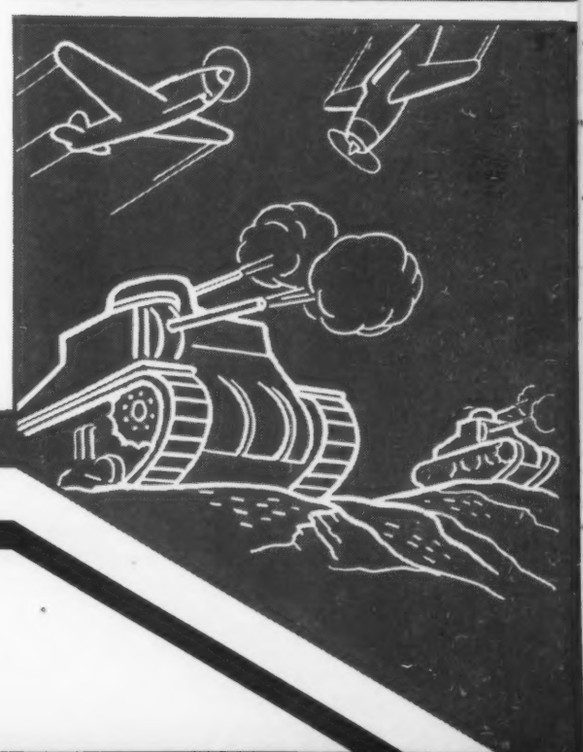






Mute evidence of what happened because the shell was defective. In battle it might mean death and defeat instead of victory

The "Reasons Why" of Shell Design As Shown by Firing Tests

Although merely a single piece of steel, a shell presents a critical design problem. Unless it is designed properly and made accurately with respect to all of its dimensions, the shell might cause disaster to the gun and its crew and, in any event, will fail to fulfill its mission.

"FIRE!" The trigger is pulled and in less time than it took to shout "fire," the shell has left the 75 mm. gun. In that short interval, 0.08 seconds, the 14 lb. projectile with its load of TNT was accelerated to a velocity of more than 1,900 ft. per sec., 1,300 mi. per hr. Simultaneously, it was set spinning about its axis at 25,000 r.p.m. For 0.08 seconds energy was poured into the projectile at the rate of 32,000 hp., equal to the entire output of 25 or more pursuit ship engines.

In a hell-fire of burning gases that develop a pressure of 36,000 lb. per sq. in. the base of the shell receives a kick that averages a quarter of a million pounds. At its momentary peak the total pressure on the base of the shell reaches 250,000 lb. or more, a crushing force that is resisted by the inertia of the projectile as it is being accelerated.

If the gun has been made right and if the round of ammunition was made to specifications in every respect, the shell will complete its flight in a few more seconds and then in a suicidal burst deliver death and destruction to the enemy. No other machine or device created by man has such a short life of service. No other machine is subjected to such terrific temperatures, forces and velocities as is a projectile. That is why every little detail of the shell must be made to exacting tolerances and specifications. The difference between a small radius and a sharp corner might cause the shell to fall short of its mark or to over-shoot, or to tumble crazily instead of following the true course. Defects that appear minor or insignificant might cause a premature explosion, wrecking the gun and killing its crew.

The complete round of fixed ammunition, as shown in Fig. 1, consists of the cartridge case, fitted with a primer and loaded with propellent charge, the steel shell loaded with its TNT, and the assembled fuze and booster. When loaded into the gun the round must fit precisely in the gun chamber with reference to both diametral and axial dimensions. In the diagrams that follow, the behavior of the steel shell when it is fired and the possible effects of imperfections in its design and manufacture are analyzed.

Perhaps the greatest hazard in the firing of shell is that of premature explosion of the bursting charge. There is still much uncertainty regarding the possible causes of premature explosion

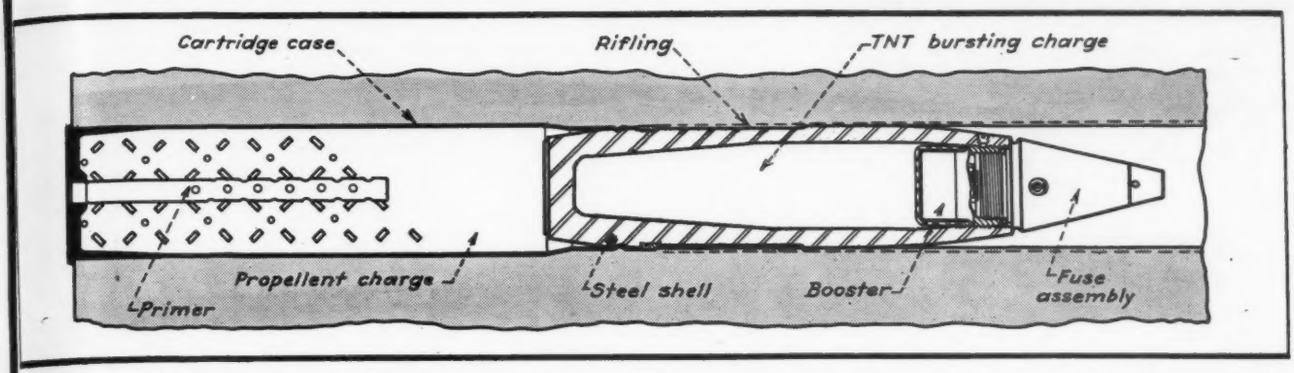


Fig. 1—Complete round of fixed ammunition—cartridge case, primer, propellent charge, shell, fuze assembly, TNT and booster

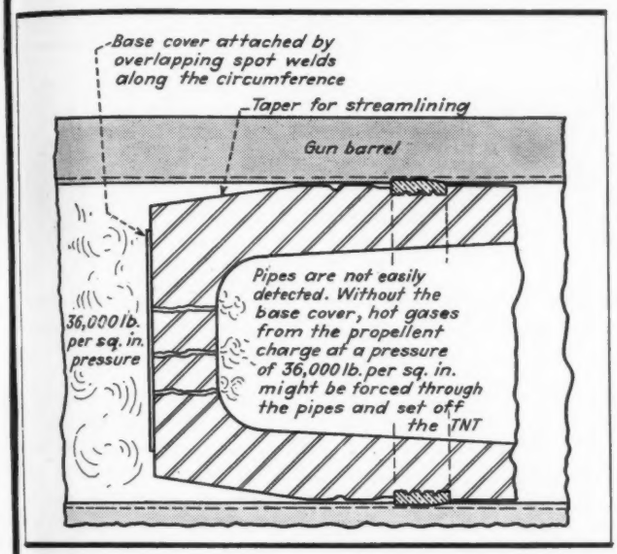

Base cover attached by overlapping spot welds along the circumference
Taper for streamlining
Gun barrel
36,000 lb. per sq. in. pressure
Pipes are not easily detected. Without the base cover, hot gases from the propellent charge at a pressure of 36,000 lb. per sq. in. might be forced through the pipes and set off the TNT

Fig. 2—Base cover prevents possibility of hot high-pressure gases getting in contact with the bursting charge

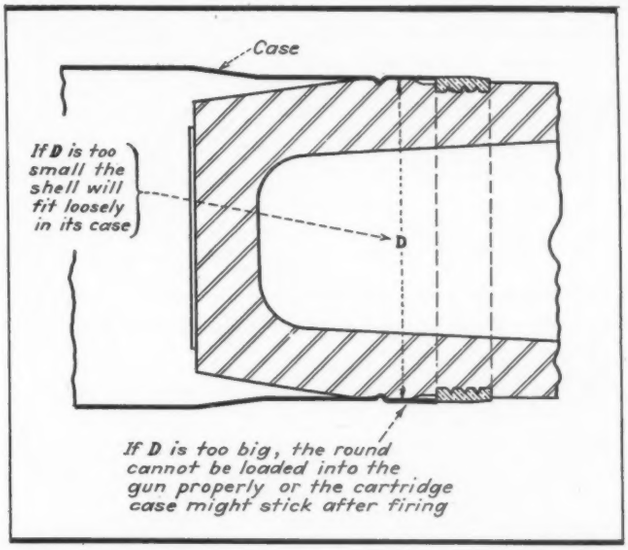

Case
If D is too small the shell will fit loosely in its case
D
If D is too big, the round cannot be loaded into the gun properly or the cartridge case might stick after firing

Fig. 3—If diameter over which the case fits is too small, fit will be loose and propellent charge might get damp

but one possible cause is the leakage of hot gases, generated by the propellent charge, passing through the base of the shell and setting off the TNT, as indicated in Fig. 2. Pipes in the shell forging would possibly provide such a passage for the hot gases.

If the ingot from which the billet was rolled was not cropped enough, the gas pockets in the cropped ingot will be rolled out as pipes in the billets. Shell made from such billets may have pipes running through the base.

It has not been proved conclusively that shell with piped bases always explode prematurely. Test shell with holes drilled axially through the base have been fired without exploding prematurely in spite of the unrestricted opening between the TNT and the hot propellent gas. But more often such shell explode prematurely. Therefore, a cover of soft rolled sheet steel is spot welded to the base of the shell in order to seal against undetected pipes.

The spot welds that fasten the base cover must overlap, as specified. Otherwise the purpose of the coverplate might be defeated. An improperly spot-welded coverplate might cause the shell to burst prematurely thereby wrecking the gun and probably killing its crew.

The taper at the base of the shell serves two purposes. It makes it easier to push the shell into the cartridge case and it streamlines the shell, thereby reducing the drag caused by a partial vacuum and air turbulence against the base of the shell while in flight. Thus, varying the taper changes the range of the shell. If successively fired shell have different tapers, their range will be erratic and it will be practically impossible to hit the target.

The crimping groove and the shell diameter at the groove may seem to be of minor importance, but if they are not right the shell might be useless. If diameter *D* in Fig. 3 is too small, the cartridge case will not seal tightly around the shell. Moisture will leak into the shell by the breathing that accompanies changes in temperature. Such shell may fall short of their mark because of the dampness of the propellent charge.

If diameter *D* is too large, the cartridge case at that point might not fit into the chamber or might even be larger in outside diameter than the rotating band. An excessively large diameter *D* will require the cartridge case to be stretched excessively when the shell is forced in, possibly causing the case to split when it is crimped to fit into the crimping groove behind the rotating band.

What happens when the crimping groove is not positioned properly is indicated in Fig. 4. If the crimp is not tight the shell will be loose in its cartridge case or might even slide out. If the shell is loose in the case it will turn when the time fuze is inserted in the fuze setter and the case is rotated by hand to give the fuze the proper time setting.

Often the order "cease firing" is given after the gun has been loaded, but before it has been fired; the shell must be extracted from the gun. The

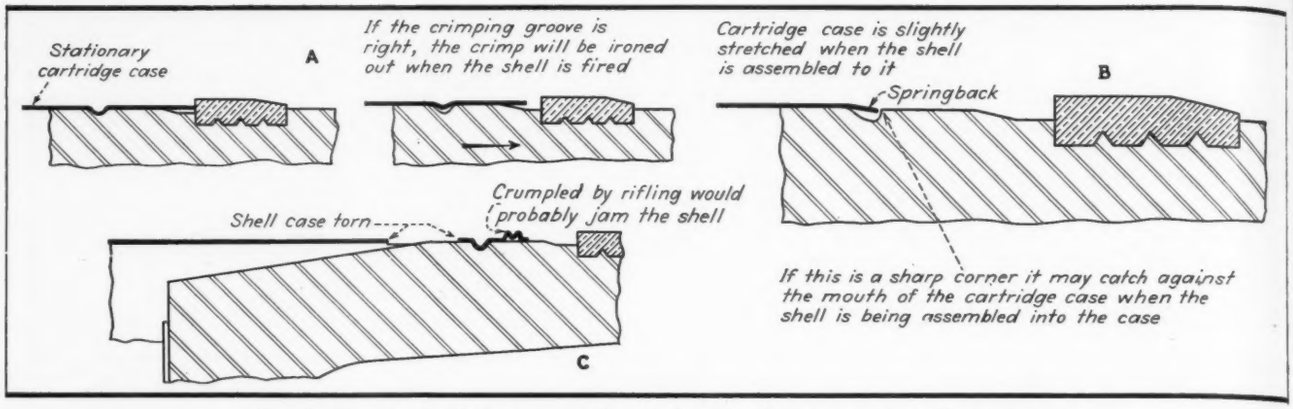

Stationary cartridge case
A
If the crimping groove is right, the crimp will be ironed out when the shell is fired
Cartridge case is slightly stretched when the shell is assembled to it
B
Springback
Crumpled by rifling would probably jam the shell
Shell case torn
If this is a sharp corner it may catch against the mouth of the cartridge case when the shell is being assembled into the case
C

Fig. 5—The shape of the cross-section of the crimping groove is highly important

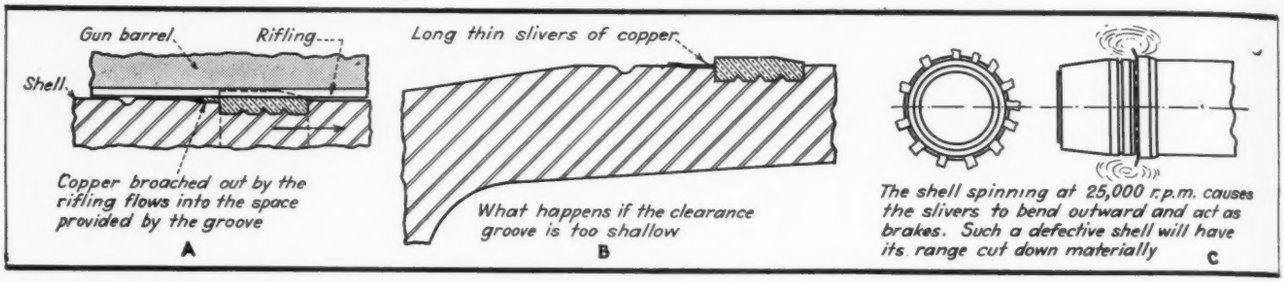

Gun barrel
Rifling
Shell
Copper broached out by the rifling flows into the space provided by the groove
A
Long thin slivers of copper
What happens if the clearance groove is too shallow
B
The shell spinning at 25,000 r.p.m. causes the slivers to bend outward and act as brakes. Such a defective shell will have its range cut down materially
C

Fig. 6—The flat-bottomed groove behind the band provides a recess into which the broached out band material can flow

rotating band usually wedges tightly against the rifling when the gun is loaded and hence when the round is being extracted, the steel shell tends to stick in the gun. When extracting the round from the gun, if the case is not crimped tightly it will be ejected but the shell will remain and the propellent powder will be spilled inside the gun, putting it out of action.

It was not a whim that dictated the unsymmetrical curved profile of the crimping groove. The diagrams in Fig. 5 show: (A) The correct grooves. (B) What would happen if the leading edge of the groove were a sharp corner. After being stretched over the base diameter, the mouth of the cartridge case contracts slightly and, therefore, would catch on the sharp edge of the groove, making it difficult to assemble the shell into the cartridge case. (C) If the trailing edge were steep, the crimp in the shell would not iron out readily when the shell is leaving the case after firing. The sharp corner might even cause the cartridge case to be torn. Brass cartridge cases are reused and the shortage of brass makes it doubly important to make reuse possible. Also a torn cartridge case might stick in the gun, putting it temporarily out of action.

The flat bottom groove behind the rotating band, as shown in Fig. 6, is highly important. Without it the copper broached out from the band by the rifling would form thin slivers, as shown. The spinning of the shell at 25,000 r.p.m. would bend the thin slivers outward on account of the centrifugal force produced. Thereby the flight of the shell would be retarded. The purpose of the shallow groove is to serve as a clearance space into which the copper from the band can flow when it is being broached by the rifling. Thus, the broached out copper instead of forming thin slivers, will form short cantilever beams that are relatively thick at the section where they join the rotating band. These short relatively heavy slivers of copper are too rigid to be bent outward by the centrifugal force.

The "rotating band" serves three purposes. (1) It positions the shell in the chamber of the gun. Obviously, the rotating band must be in the correct position and the taper on the band must conform to the taper of the end face of the rifling. If there is too much space between the band and the beginning of the rifling, the band will receive a terrific impact when it meets the rifling. (2) The band also serves as a seal between the shell and the gun barrel. If the band is too small, hot gases will rush through the clearance space and severely score the rifling. If the band is too large in diameter, the shell will drag, sometimes to such a degree that some of the copper of the band is "plated" on the surface of the gun barrel. (3) The "copper band," which is really Gilding metal, 90 Cu.-10Zn. is broached by the

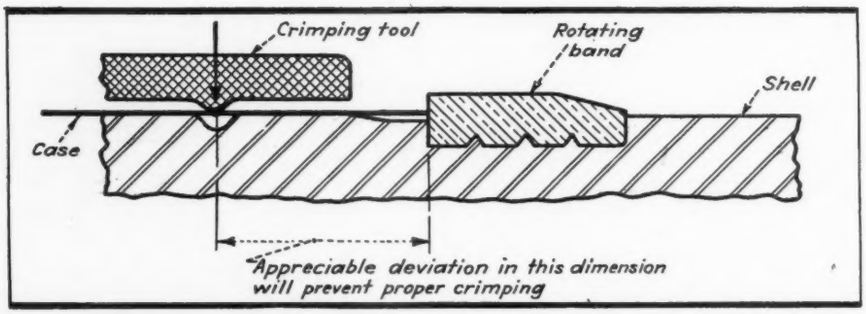


Fig. 4—If the crimping groove is not in the right position, it will be impossible to crimp the case properly

rifling and transmits to the shell a sudden twist as the shell passes through the gun. Thus, in 0.08 sec. torque is transmitted through the rotating band to the shell and sets it spinning at 25,000 r.p.m. This requires a tangential force of about 1,500 lb. acting between the bottom of the band and the shell. This amounts to about 350 lb. per sq. in. of contact area between the band and the shell, a force which is transmitted to the shell by the grip of the band on the scored band seat.

If the bottom of the band groove in the shell has not been scored properly, the band might possibly slip and fail to spin the shell. If as indicated in Fig. 7, the band seat diameter is too large, the band would be correspondingly thinner and, therefore, might tear out and jam the shell. If the base diameter of the band seat is too large and the diameter across the flat groove directly behind the copper band is too small, there will be a correspondingly smaller area for the rear face of the copper band to bear against. The unit compressive stresses against the rear face of the copper band will be correspondingly higher because of the insufficient bearing area, and it is possible that this will cause the copper band to tear as the shell enters the rifling.

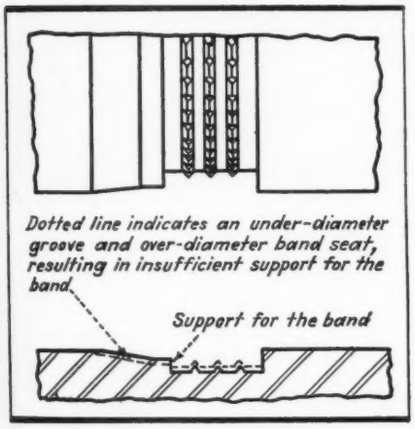

Dotted line indicates an under-diameter groove and over-diameter band seat, resulting in insufficient support for the band.
Support for the band

Fig. 7—The band seat must be of correct diameter and properly scored

The point of highest stress in the shell is at the section ahead of the rotating band, as indicated in Fig. 8. At the rotating band a radial compressive stress exerted by the band slightly reduces the compressive stress caused by the "set back" force. The "set back" force is the total compressive stress developed in the shell by the pressure of the propellent charge. The "set back" force decreases toward the nose of the shell. At the section indicated, the combined stress resulting from set back plus the stresses arising from the centrifugal force of the spinning shell, is at maximum, almost reaching 60,000 lb. per sq. in., the yield point of the material.

A porous shell wall or eccentricity in wall thickness might cause the shell to "banana." This might cause the shell to stick in the gun and in any case it would score the rifling and the shell would go wild.

From the rotating band to the bourrelet, the shell is machined to a smaller diameter in order to minimize the amount of highly accurate machining required. For this dimension on a 75 mm. shell a tolerance of about minus 0.010 in. is permitted, which gives that much additional clearance between the shell and the bore of the gun. Because this is a clearance diameter, it is sometimes erroneously concluded that the minus tolerances can be exceeded. This is not permissible because of the variation in weight that would result. The total allowable variation in the weight of a 75 mm. shell is limited to about plus or minus 0.3 lb. The minus 0.01 in. tolerance at the clearance diameter of the shell will cause a maximum variation in the weight of 0.11 lb. which alone is 1/6 of the total allowable variation in the weight. Also, a clearance diameter less than the minimum allowable would correspondingly decrease the cross-sectional area of the shell at the section of critical stress.

The diameter of the shell at the bourrelet and ogive has a tolerance of minus 0.005 in. The bourrelet section of the shell bears on the rifling, the rotating band and the bourrelet providing the two points at which the shell is supported in its travel through the gun. Obviously, if this fit is not accurate the shell will not fire accurately.

The ogive is extremely important because it provides the streamlining for the nose end of the shell. Any change in the contour of the ogive will affect the range of the shell.

At the nose end of the shell are five equally-spaced notches placed 72 deg. apart. Because they are merely notches, their importance is often overlooked. They are the staking notches by which the fuze is locked in place after it has been assembled to the shell. Five notches are provided but usually only four of them are used. The additional notch is provided so that it will never be necessary to stake the fuze at the point where the wrench slot is located. In spite of the fact that the fuze staking notches are extremely simple to make, they are often made too deep or too shallow, perhaps simply because the inspectors and production men do not realize the importance of them.

Other factors that have marked effects on shell are eccentricity between the bore of the shell and its outside diameters, and the ballistic characteristics of the shell. Ballistics is a complex mathematical subject by means of which the proportions of a shell are determined to assure true flight. Needless to say, an improperly made shell that does not have the required weight distribution for true flight will be useless.

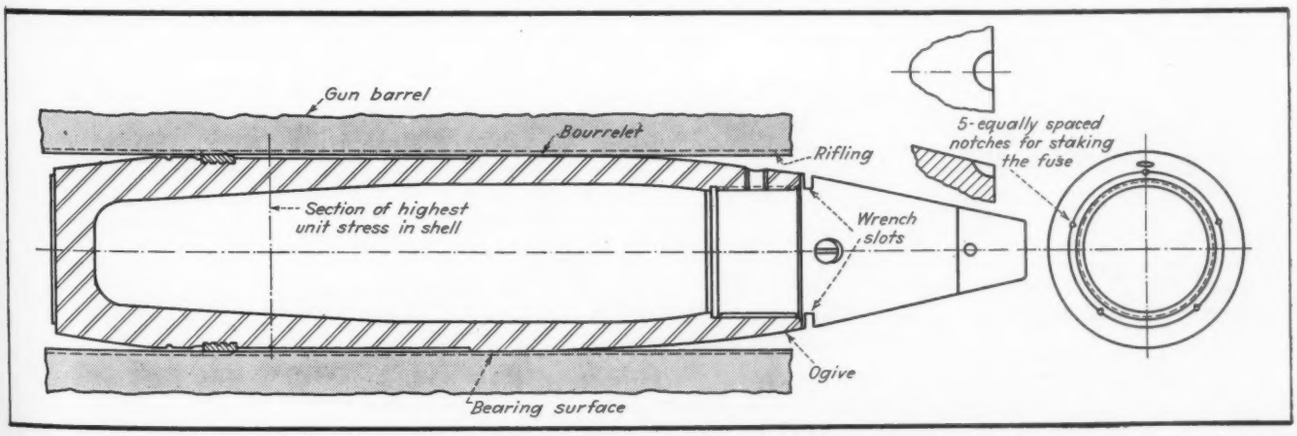


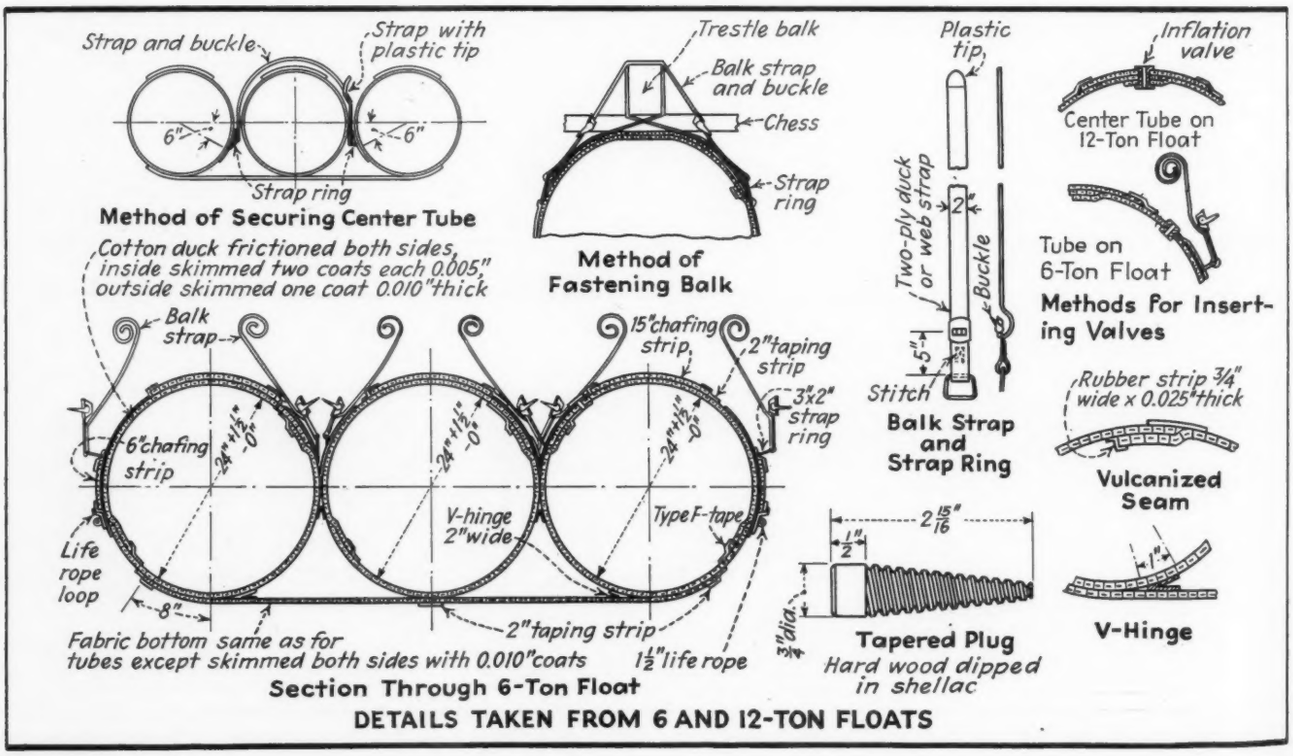
Fig. 8—The point of highest stress in the shell is at the cross-section ahead of the band a distance equal to the wall thickness

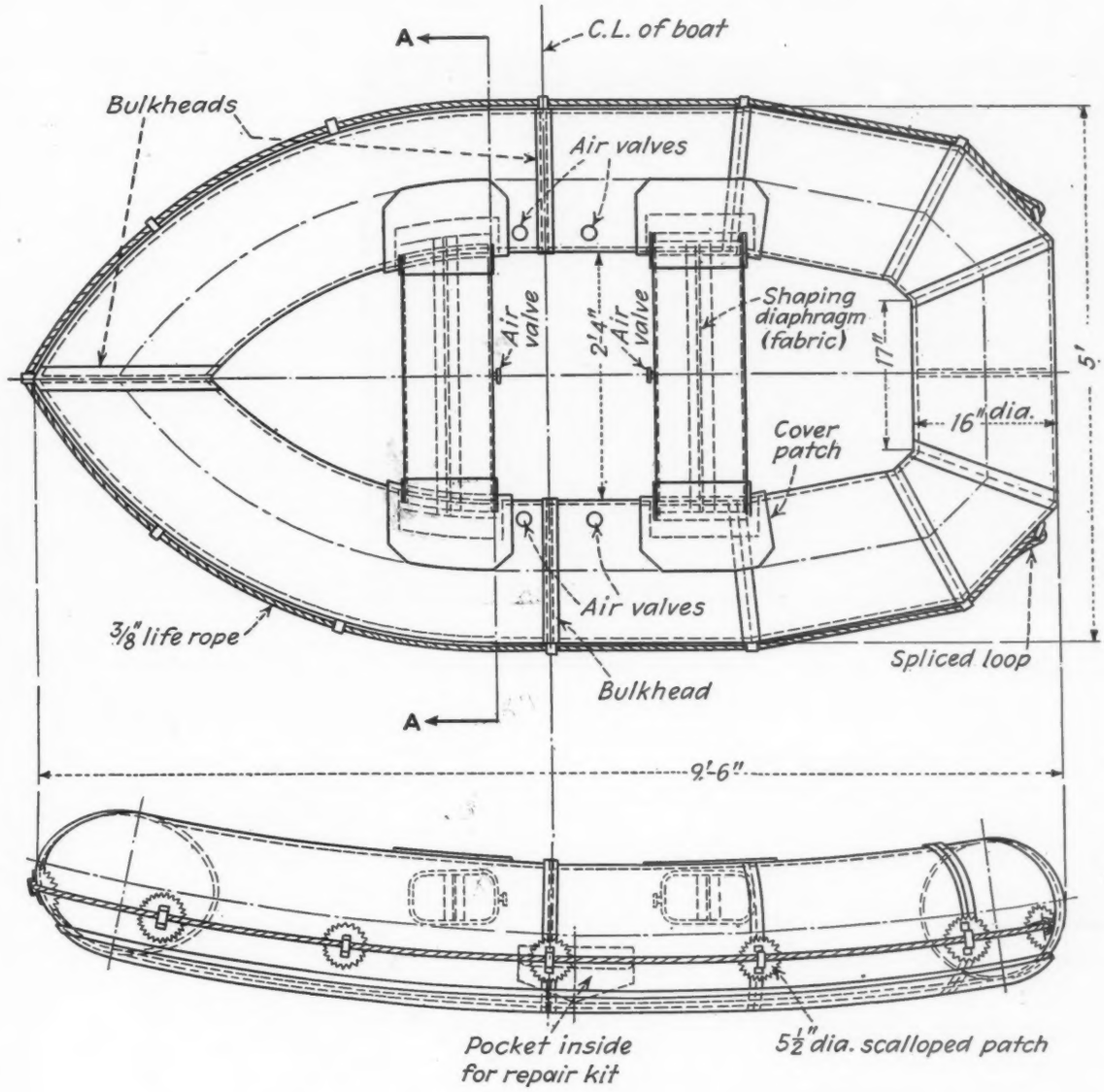
WARTIME DESIGNS . . .

ARMY'S RUBBER FLOATS SAVE TRUCK SPACE

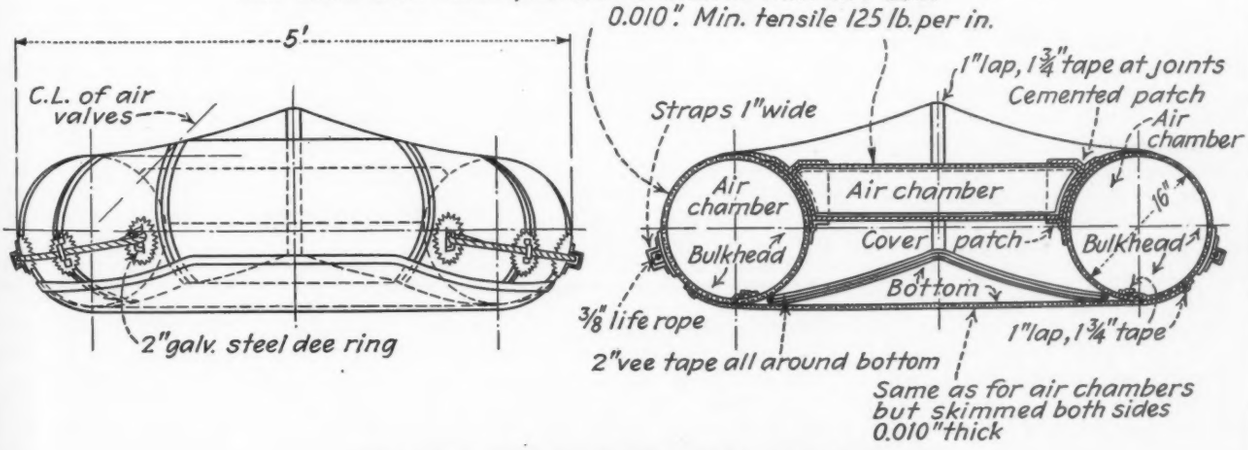
Pneumatic pontons designed by Corps of Engineers will speed Army river crossings in bridges such as the one shown at right, and as barges and reconnaissance boats. In contrast to steel or aluminum pontons, pneumatic equipment is light in weight (6-ton float, 6x20 ft., weighs only 375 lb.), can be packed into compact carrying cases, and requires fewer trucks to move a bridge. Pneumatic tubes are compartmented, and bullet holes can be repaired quickly. Material is rubberized cotton duck with weights and thickness of coating as shown on drawings. Rubber compound used in frictioning or skimming is 40 percent crude rubber, 30 percent reclaimed rubber, remainder carbon black, mildew inhibitor, etc. Seams can be either cemented or vulcanized. All seams have 1-in. lap, develop full strength of fabric. For cementing, seams are buffed, coated with self-curing rubber cement, assembled and allowed to cure for 3 days before packing. Valves are brass; other hardware is galvanized steel. Emergency repair kit contains patches, rubber cement, valve repair parts, and wooden plugs for bullet holes. Corps of Engineers specifications T-1231A, T-1230A, and T-1182D give more complete details.

Official U. S. Army Photo



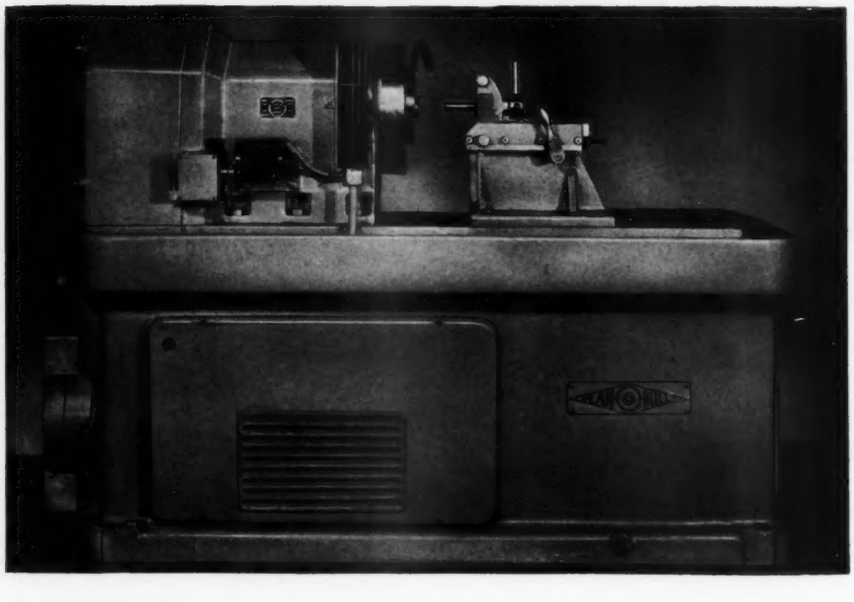


Cotton duck frictioned on both sides. Inside skimmed with two coats each 0.005", outside skimmed with one coat 0.010". Min. tensile 125 lb. per in.

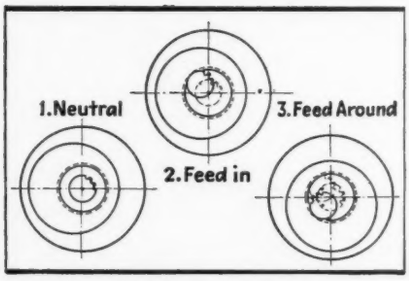


PNEUMATIC RECONNAISSANCE BOAT

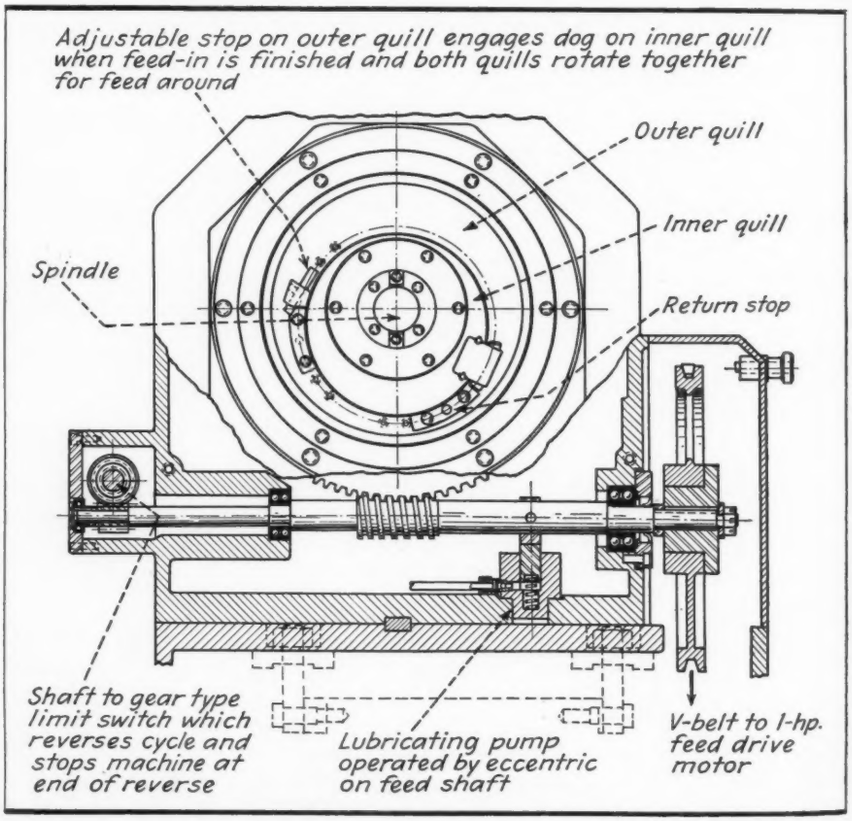
ELECTRONIC MOTOR CONTROL CHANGES CUTTER FEED IN MID-CYCLE



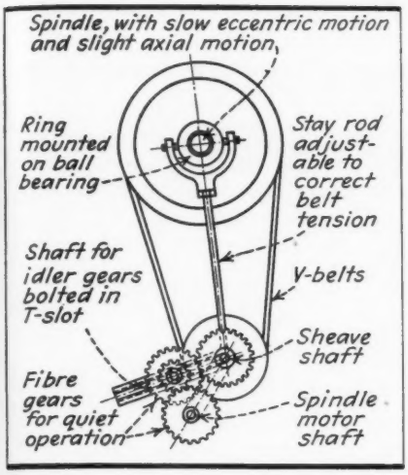
A compact electronic unit gives automatic cyclic control of the d.c. feed motor in Plan-O-Mill Corporation's No. 3 planetary milling machine. Starting at the push of a button, it feeds the milling cutter into the work at a preselected speed, automatically switches a few seconds later to another preselected speed for feed-around, rapid reverses the feed motor at the end of the milling operation, and shuts off the motor at the end of the cycle. The electronic system, an adaptation of General Electric Company's comparatively new Thy-mo-trol, was chosen by Plan-O-Mill engineers for its compactness, simplicity, lower cost for this small machine, and for its flexibility in providing stepless control of feed. Thy-mo-trol electronically converts a.c. into controlled d.c. which powers the feed motor mounted in the base.



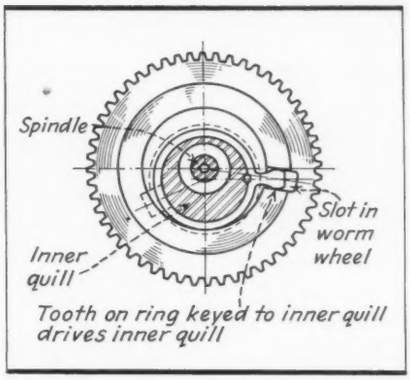
Principle of planetary milling: Work piece is fixed. Milling cutter revolves on an orbit inside or outside of the work to mill the contour or threads. Cutter spindle is mounted in two quills, each of which has 5/8-in. eccentricity. Cutter starts at central position. Inner quill rotates on its center, feeding cutter on an eccentric path into the work. When full depth of cut is reached, inner quill engages outer quill, and two quills rotate together to carry the milling cutter around in a circular path for slightly more than one revolution. In threading operations, the cutter also advances axially one lead. Head operation then reverses automatically at fast speed, returning cutter to starting position in 12 to 15 sec. Because maximum cutter life cannot be reached with same feed-motor speed for feed-in and feed-around, the Thy-mo-trol was designed to give selective speeds for both feed-in and feed-around, and to automatically change from one of these speeds to the other at instant when outer and inner quills engage and cutter begins to feed around.


Adjustable stop on outer quill engages dog on inner quill when feed-in is finished and both quills rotate together for feed around
Outer quill
Inner quill
Spindle
Return stop
Shaft to gear type limit switch which reverses cycle and stops machine at end of reverse
Lubricating pump operated by eccentric on feed shaft
V-belt to 1-hp. feed drive motor

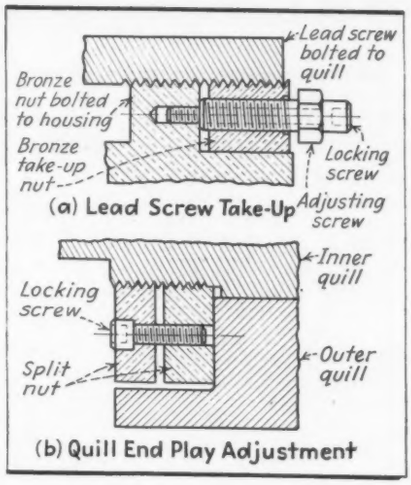
Inner quill is driven by 1-hp. d.c. feed motor through V-belt, worm gear and the driver ring shown on opposite page. Worm shaft, through a second set of worm gears, drives gear-type limit switch which reverses feed motor. Dog attached to inner quill engages adjustable stop on outer quill so both quills rotate together for feed-around. Adjustable stop is mounted approximately at point where cutter starts to feed into work; adjusting screw is then set so quills engage the instant cutter has reached full thread depth.


Spindle, with slow eccentric motion and slight axial motion
Ring mounted on ball bearing
Stay rod adjustable to correct belt tension
Shaft for idler gears bolted in T-slot
V-belts
Sheave shaft
Fibre gears for quiet operation
Spindle motor shaft

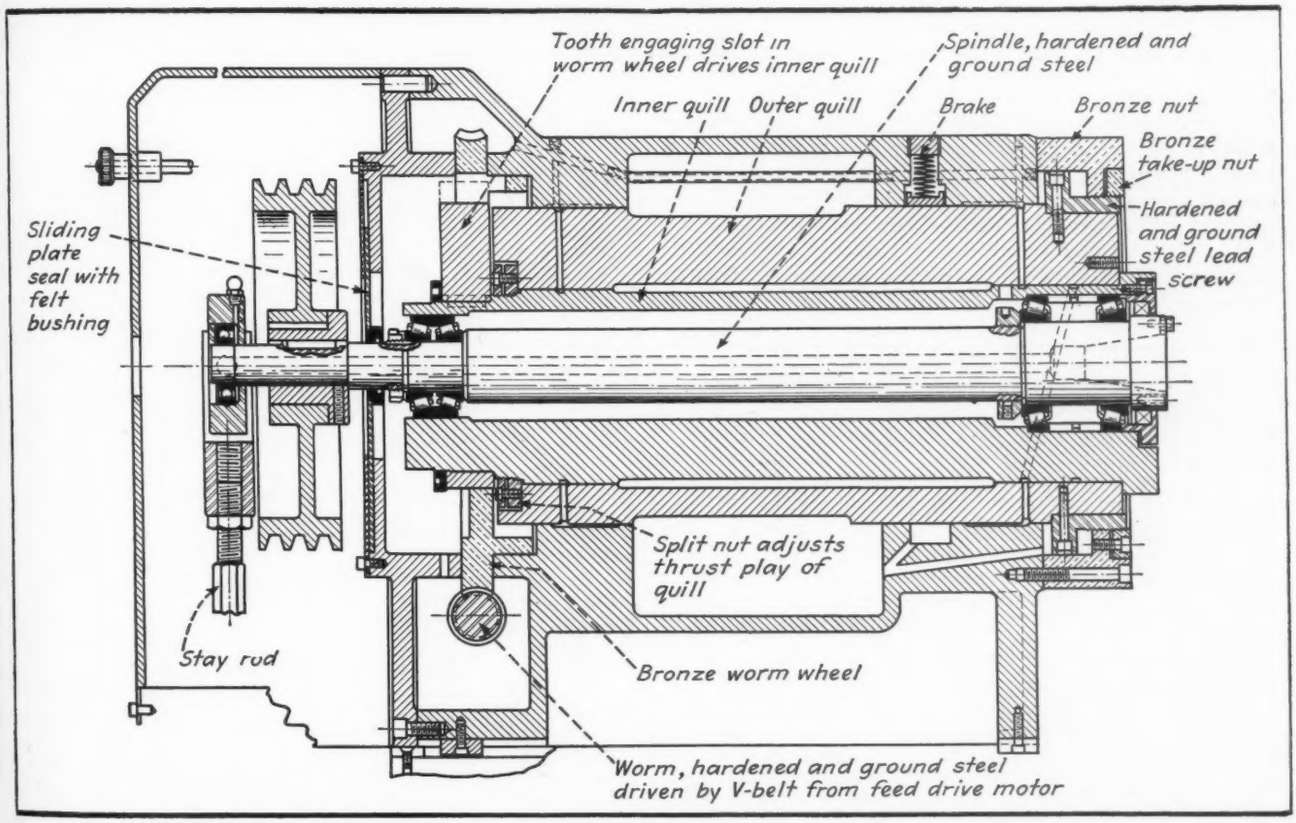
Spindle drive is complicated by fact that spindle moves in an orbit and also has slight axial motion caused by lead screw which gives proper pitch to threads. Original drive was V-belt from spindle to motor which was mounted on hinge so that weight of motor was supported largely by belt. Stay-rod and change-gear unit is now used.



Drive of inner quill also is complicated by eccentric motion of quill. Solution was this driving ring with single tooth which engages slot in worm gear. Ring is keyed to inner quill, and is held in place by ring nut. Tooth has cylindrical form and drives quill both forward and reverse. Side view of this driving ring given in drawing below shows clearance provided in worm gear slot to allow for both axial and eccentric motion of quill. Worm wheel is bronze; toothed ring is steel.



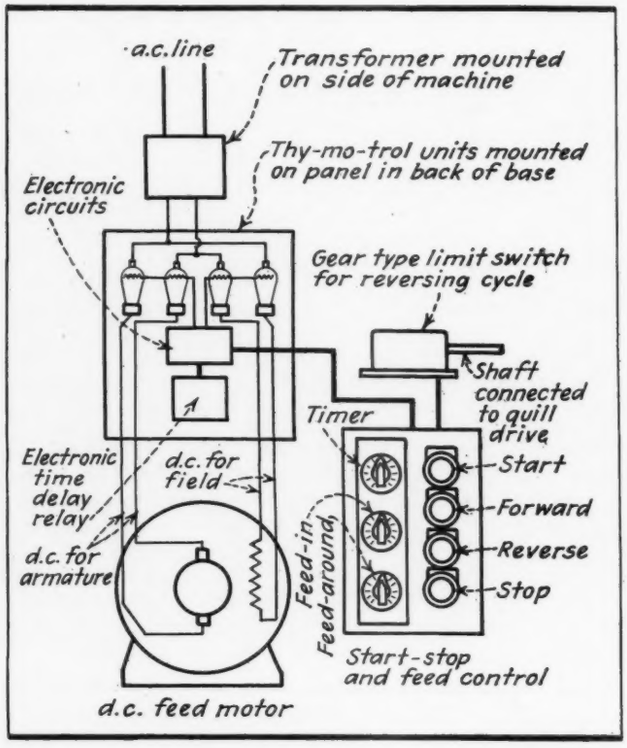
Play in lead screw is eliminated by take-up nut adjusted by six screws. Adjusting screws are hollow, and are locked by smaller screws passing through their centers as shown in top sketch. Bottom sketch shows detail of split nut which takes up end play of inner quill. Split nut is jammed in proper position by setscrews.


Tooth engaging slot in worm wheel drives inner quill
Spindle, hardened and ground steel
Inner quill
Outer quill
Brake
Bronze nut
Bronze take-up nut
Hardened and ground steel lead screw
Sliding plate seal with felt bushing
Split nut adjusts thrust play of quill
Stay rod
Bronze worm wheel
Worm, hardened and ground steel driven by V-belt from feed drive motor

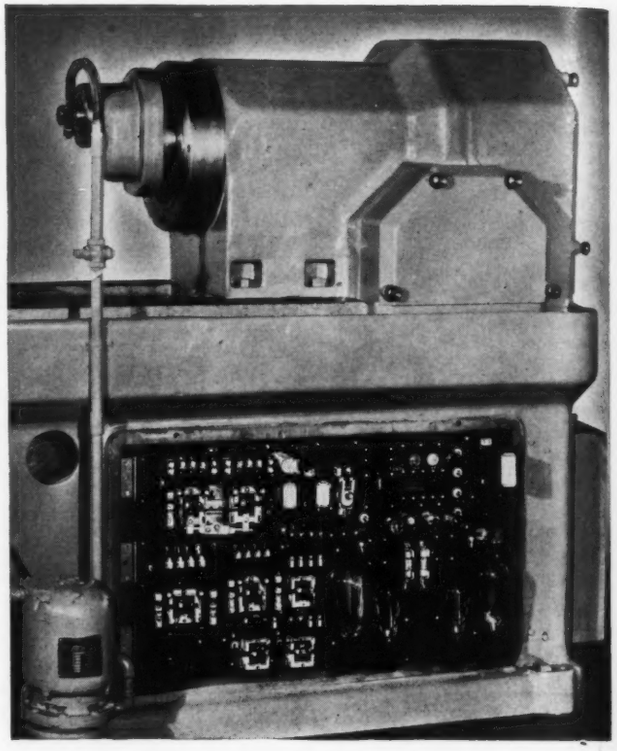
Principal mechanical problems in design of Plan-O-Mill were those of driving and sealing spindle and inner quill, both of which travel on eccentric orbits. Quills are plain cast iron, and since their rotation is at low speed, no special bearings are required. Front bearings of spindle are pre-loaded pair of Timken tapered roller bearings with class 0 fit. Oil retainer is Perfect type. Rear spindle bearing is Timken tapered roller, double row, class 3 fit, with outer race free to slide axially in inner quill to allow for spindle expansion. Oil seal at rear of housing is sliding plate with felt bushing around spindle. Lubrication system shown is fed by cam-operated pump, and reaches all bearings and bearing surfaces on quills and spindle.

(continued on next page)

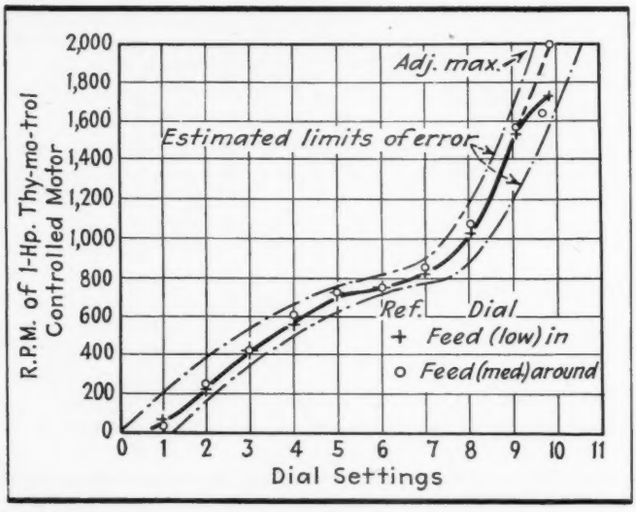
ELECTRONIC MOTOR CONTROL (continued)



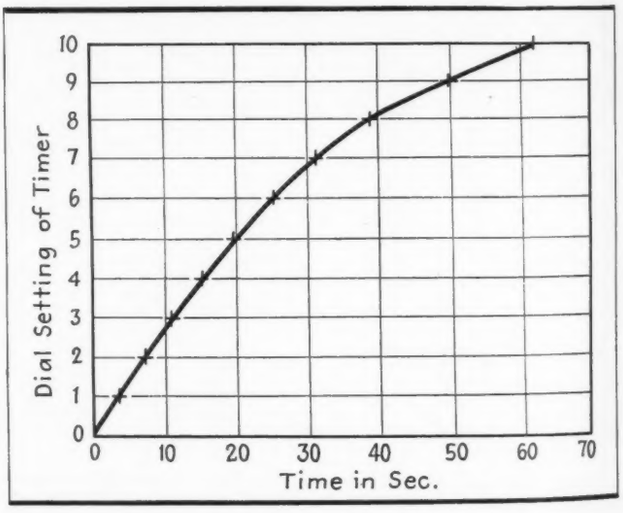
Thy-mo-trol system, shown in schematic above, employs electron tubes to convert a.c. into controlled d.c., thus providing variable armature and field voltages for the d.c. feed motor. Top one of three rheostat controls at work station controls electronic time-delay which changes speed of feed motor at instant when feed-in stops and feed-around begins. Middle rheostat sets speed of feed motor during feed-in. Bottom rheostat adjusts feed-around. Gear-type limit switch throws feed motor into rapid-reverse at end of feed.



Panel located at rear of machine base contains all elements of electronic circuit, arranged in easily accessible units. As with any electronic device, principal cause of failure is burned out tubes, and can be corrected in a short time by simply replacing the tubes. Power tubes are General Electric thyratrons. Thy-mo-trol system also contains a thermal relay which shuts off the motor before sustained overloads can cause damage. The electronic circuit brakes the motor dynamically to prevent time-wasting slow-down of the cutter.



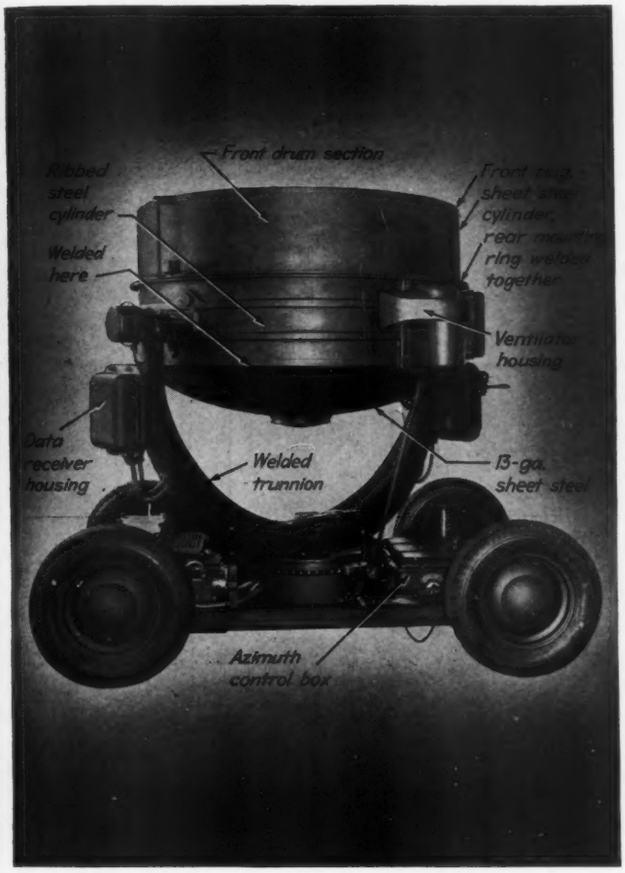
Graph of motor speed vs. rheostat setting shows that motor speed can be predetermined within close limits. Reason for leveling-off of curve near setting 5 is that Thy-mo-trol controls motor speed by increasing armature voltage (full field) from settings 1 to 5, and by weakening the field (armature voltage constant) from settings 5 to 10.

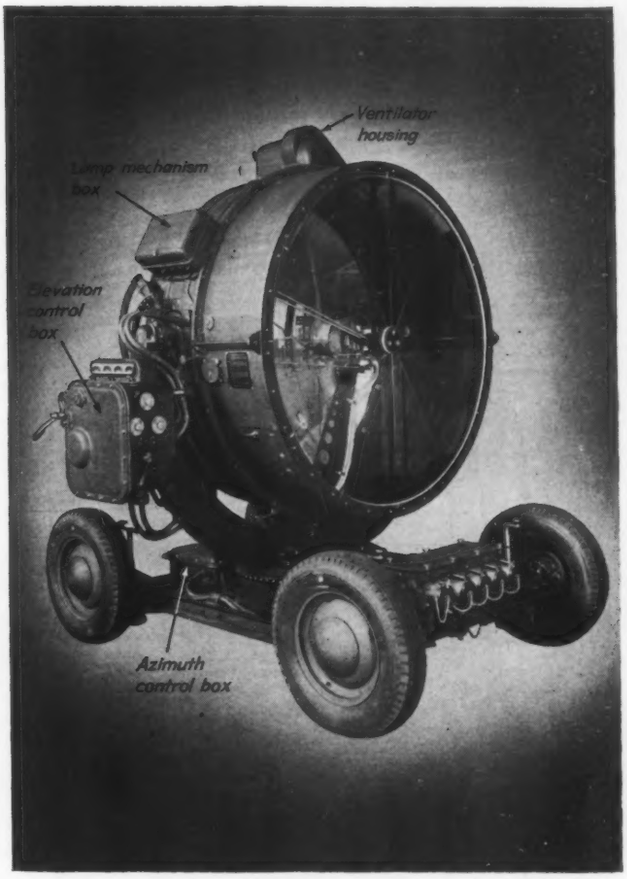


Graph of actual time vs. dial setting for electronic time delay relay aids in setting time of automatic change-over from feed-in to feed-around speeds of feed motor. Time delay relay should be set to act at same number of seconds as required for inner quill to feed tool to full depth and engage outer quill. The circuits compensate for voltage variations.

ALUMINUM IN ARMY SEARCHLIGHTS REPLACED BY STEEL STAMPINGS

700 lb. of aluminum sheet and castings have been eliminated from Army's giant 60-in. searchlight by fabricating it from formed sheet steel and malleable iron castings. Principal problems were to maintain all essential dimensions so that gears and other internal parts need not be changed, and to keep down the weight. Only changes in internal parts were minor ones in hardware and dowels. First steel searchlight was only 65 lb. heavier than aluminum model. Weight has since been further reduced. Redesign was done by General Electric Company and Murray Corporation of America.





Drum is fabricated from pressed steel parts welded together. Front ring, sheet steel cylinder, and rear mounting ring are welded together to form front drum section. Sliding doors and other small items on front drum section are malleable iron castings or fabricated from sheet steel. Rear drum section is two pressed steel pieces welded together at mirror mounting position. Cylindrical piece has circumferential ribs for strengthening. Additional ribs at lower section of drum strengthen mounting of lamp column. Head, formerly a $\frac{3}{8}$-in. thick aluminum casting, is now formed on a big auto body press from 13-ga. sheet steel, is 70-in. dia. before trimming. Ventilating housing mounted on rear drum section is fabricated from pressed steel parts.

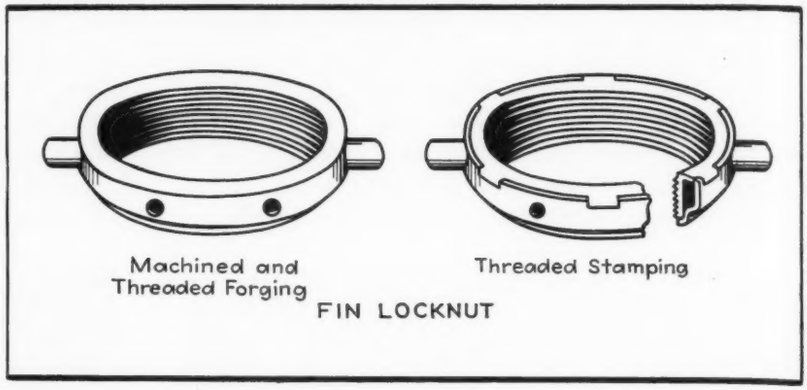
Trunnion arms are fabricated from U-shaped channels welded into rectangular section. To the trunnions the two halves of the turntable top are welded. Trunnion bearings and housings are malleable iron castings and the data receiver housing on the left trunnion is pressed steel bolted to the malleable iron casting. Bearing brackets and other brackets are either malleable iron castings or steel. Base housing of the searchlight is now made of sheet steel.

Elevation control box is fabricated of pressed steel. Motor and gearing are supported by a malleable iron casting riveted to left side of box. This malleable iron casting also houses the elevation brake assembly and the socket and gearing for hand controller bar. Internal parts are supported from a steel bar welded to the lower surface of the top side of the elevation box. A platform for mounting the meters is welded to the upper side of the top of the box and the pressed steel meter cover is screwed to this platform. New method of mounting the glass in the meter housing uses a rubber gasket type of seal such as is used in rear windows of automobiles.

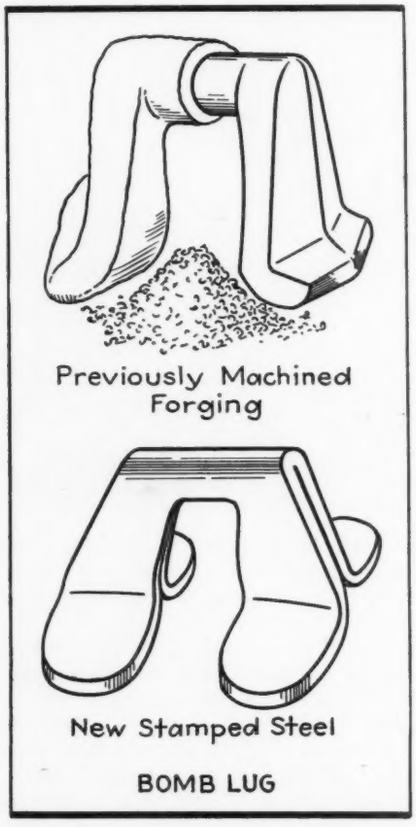
Lamp mechanism box is constructed from pressed steel parts, and is bolted to rear drum section. Mounting of equipment within this box is the same as for aluminum searchlights with exception of possible small changes in hardware. Azimuth control box is of pressed steel construction but has large malleable iron casting for mounting internal gearing and selsyns. This malleable iron casting is welded to pressed steel box at four points. These are points at which the whole azimuth box is supported on brackets from the base casting.

STAMPINGS REPLACE CRITICAL FORGINGS IN ORDNANCE

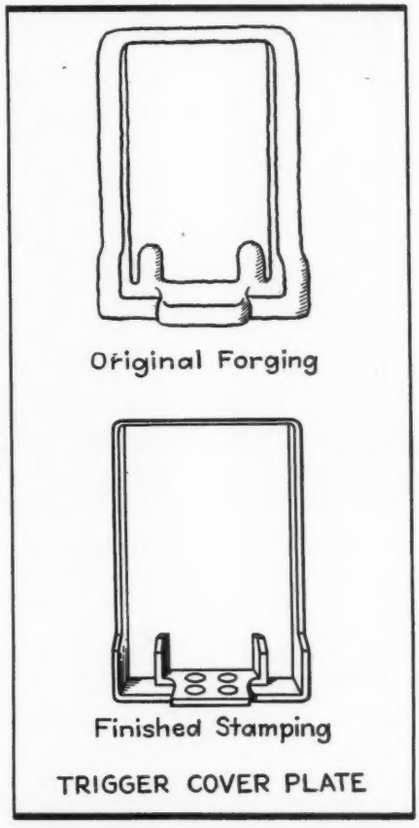
How far the United States fighting forces can go depends to a large extent upon how far engineers can make materials go. There is no advantage in three times the steel production, for instance, if the Axis makes their steel go three times as far. Thousands of items that the Ordnance Department of the U. S. Army and its contractors are now making from critical materials on critical machines must be made from less critical materials by mass production methods on less critical machines. Much of this redesign work has already been done, and in it stampings are playing an important part, as these examples of Ordnance parts show.



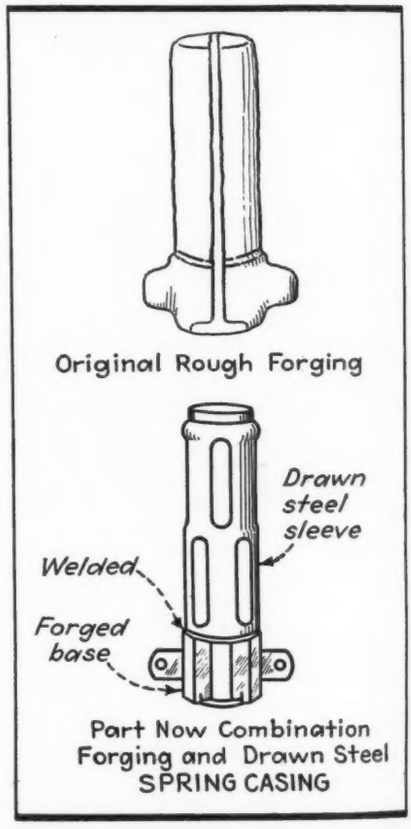
Fin lock nut for a bomb was once slowly forged, machined and threaded. Now it is stamped and threaded with 100,000 machine tool hours saved for each 2,000,000 produced—much-needed man hours that can be applied to some other bottleneck. The steel gained by this changeover will make 11,500 Garand rifles and the economy or money difference amounts to more than $250,000. Money savings, too, are important to the war effort.



A lug is a trifle but thousands of bombs were waiting for lugs, lugs previously made wastefully and slowly by forging and machining. This redesigned lug of pressed steel put otherwise idle stamping presses to work mass producing it. On one single lot of 100,000 bombs, 17,000 lb. of steel and 8,000 machine tool hours were saved.

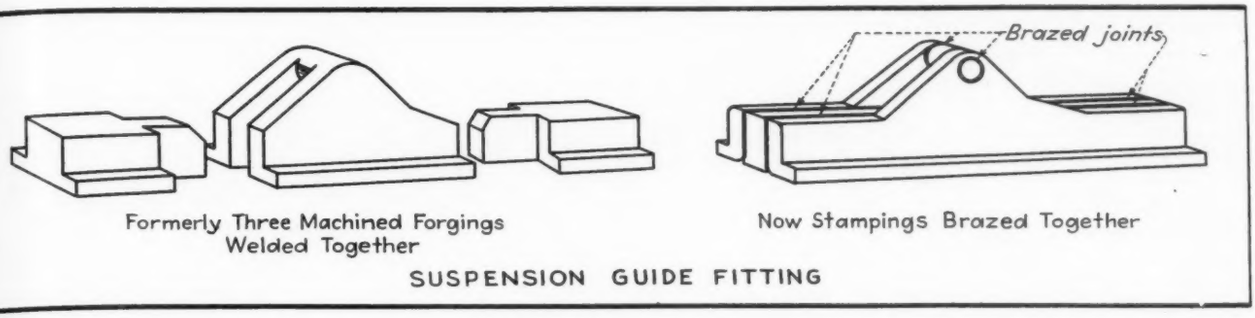


A little trifle like a trigger cover plate can be of tremendous moment to the war effort when properly redesigned. This type was forged from steel and then underwent 29 machine operations, some of which were on critical machine tools. By using a sheet steel stamping the 29 machine operations were replaced by 7, all non-critical.



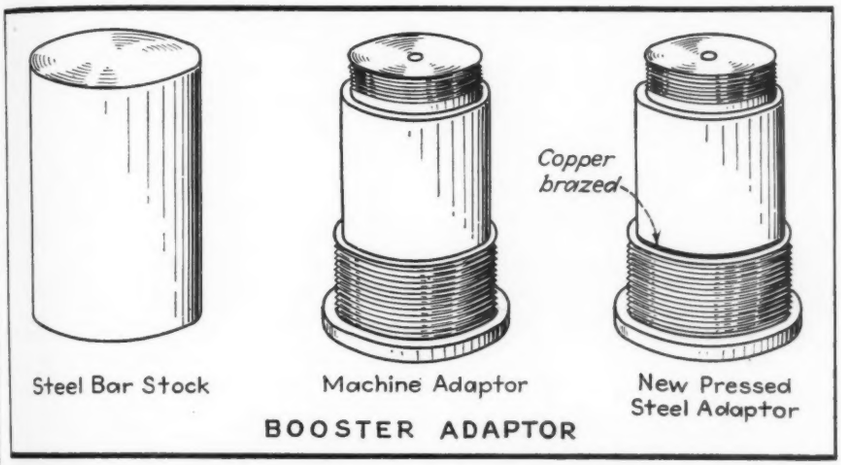
Fifty pounds of steel were machined from a 56-lb forging to make a 6-lb. gun spring casing—a dramatic waste of material. By redesigning this to use a forged base welded to a drawn steel sleeve, 42 lb. of steel, 3 man hours and $18 were saved on each and every one turned out. Redesigns such as this should not be unusual.

BRAZED ASSEMBLIES SAVE MATERIAL FOR ORDNANCE



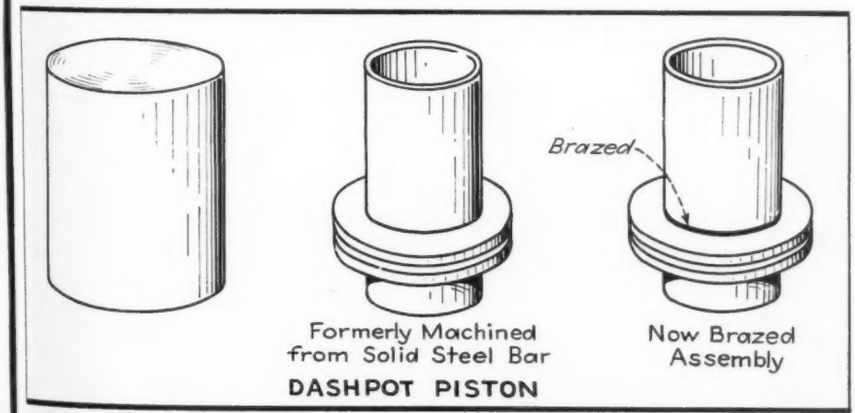
SUSPENSION GUIDE FITTING

Suspension guide fitting was formerly assembled and welded from three individually machined forgings. Today three steel stampings brazed together have reduced the cost of this item from $2.35 to 68 cents each.



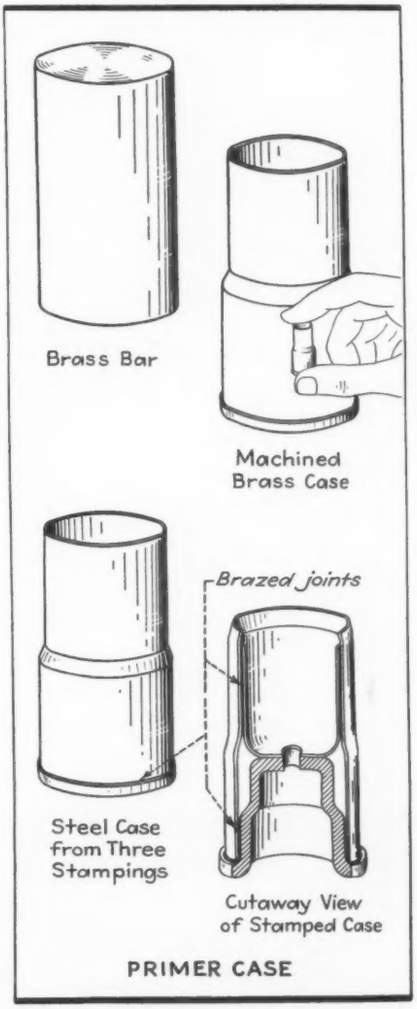
BOOSTER ADAPTOR

Burdensome multiplicity of sizes of fuzes used in shells has been reduced by the employment of adapters. One type of adapter weighs only 1.81 lb., and yet a steel bar weighing 3.85 lb. and 0.23 machine hours were necessary in its manufacture. To reduce this production waste, an adapter was designed that could be pressed from sheet steel and brazed. On 1,500,000 of these pressed steel adapters the saving in metal will be enough to produce 3,060 one-ton bombs. Furthermore 25 screw machines and 210,000 machine tool hours will be released in two Ordnance Districts alone.



DASHPOT PISTON

In a one-piece piston weighing only 1.12 lb., a steel bar weighing approximately 8 lb. was used for its manufacture. Redesigned for two-piece construction, a bar of cheaper steel weighing only 1.12 lb. and a 0.73-lb. steel plate, brazed together, saved nearly half a ton of steel and 60 percent of the machining time on each day's production, on one contract.

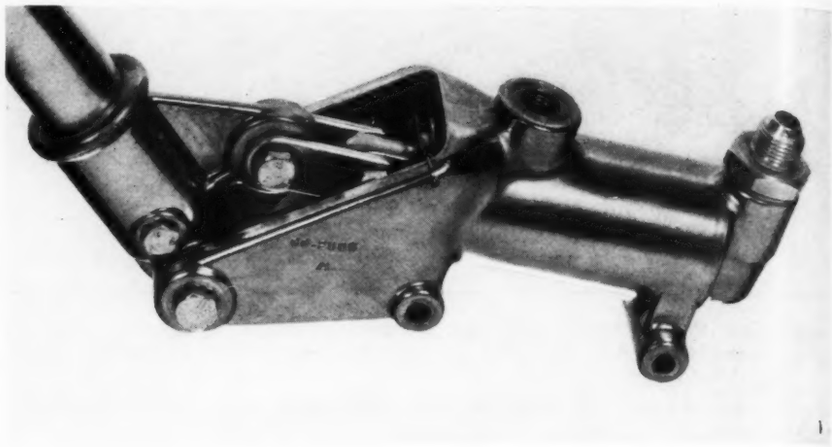


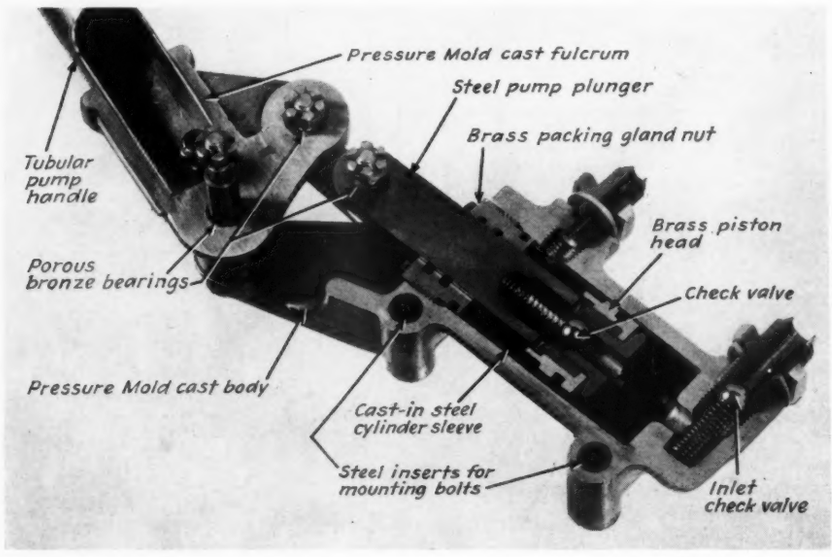
PRIMER CASE

Primer case used in munitions was formerly machined from brass bar stock and weighed 0.0625 lb. when finished. It is now being pressed from sheet steel in three parts and assembled. This will release 23,352,000 lb. of brass through 1943 for more critical uses. Many metal stamping shops in this country were idle and hungry for orders until these and like changes were made.

PRESSURE MOLDED PARTS SIMPLIFY MACHINING

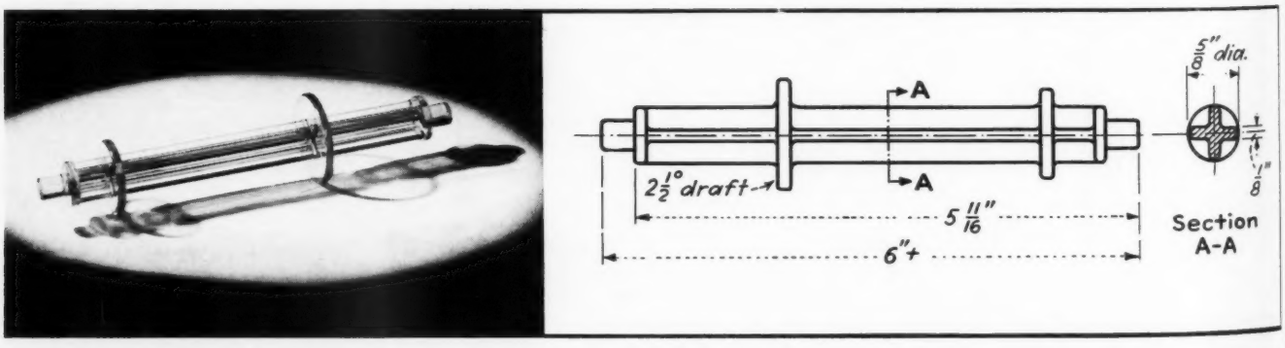
To relieve congestion on other machine shop equipment, this hand pump for aircraft was designed by Harvill Corporation so that all machining can be done on a drill press with simple tools. Inclusive of handle and fulcrum, it has only 13 different parts. Body and fulcrum are cast of 13X aluminum alloy by Harvill pressure mold process, which gives close tolerances requiring minimum of machining. Only one jig and 7 drill press tools are required to finish-machine the body. By changing inserts in pressure mold die, mounting pads may be changed in width to meet customer specifications. Capacity of pumps is 1½ cu.in. displacement.





Relatively non-strategic materials are used wherever possible. Piston rod, links, separators, and valve seat are of low-carbon steel. Piston head and gland nut are of commercial brass instead of the commonly used but strategic Tobin bronze. Aluminum body and fulcrum is required for light weight. Steel cylinder sleeve is hardened, ground and honed, then inserted in the pressure mold die and cast in place in the pump body. Piston rod is hard-chrome plated and precision ground. Super Oilite bearings are used at all three pins. Life tests of the materials selected show that wear after 120,000 cycles is negligible and leakage is substantially within AN specifications. Maximum handle load is 40 lb. at 1,000 lb. per sq.in. at 80 deg., F., and the pump meets specifications at −67 deg. F.

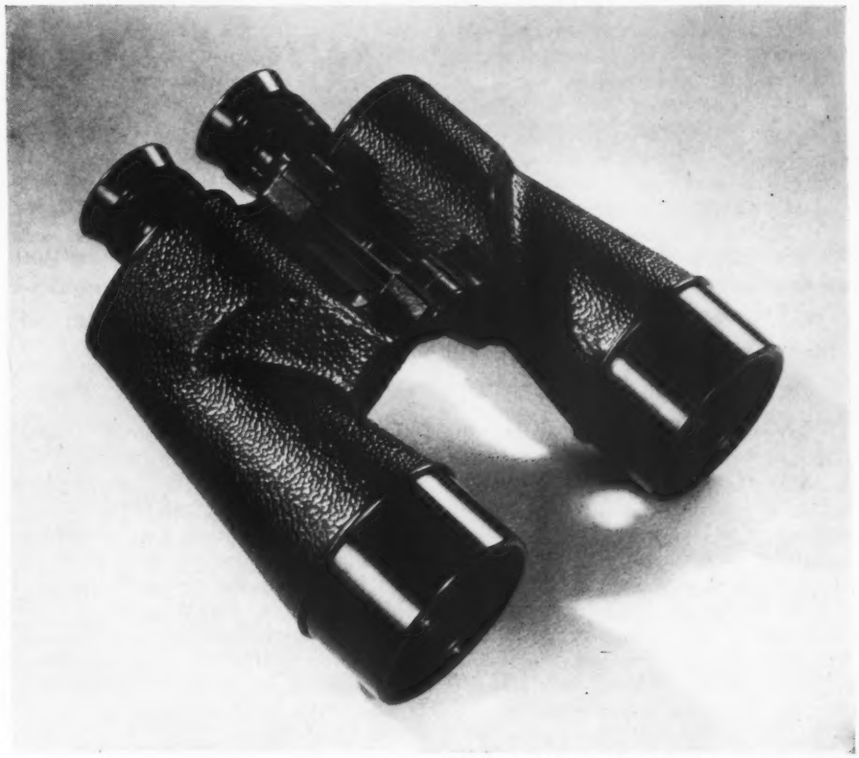
PLASTIC REPLACES ALUMINUM IN BELT ROLLER



Strategic aluminum is replaced by molded cellulose acetate butyrate (Tenite II) in this roller for machine gun cartridge belts. Plastic roller weighs 50 percent less than previous aluminum roller—an important factor since in is used in aircraft. Material is required to withstand temperature range from −40 to +160 deg. F. without deformity or tendency to break down. Diameters hold concentricity of ±0.010 in. Complete roller is molded in one operation on an automatic press by Erie Resistor Corporation, and requires no finishing operations.

VINYL COVERING FOR INSTRUMENTS RELEASES RUBBER

Rubber used in covering optical instruments and other essential wartime equipment can now be released for use where no suitable substitute can be obtained. At the instigation of the Army-Navy Munitions Board, the plastics industry has developed since May, 1942, a vinyl plastic material which conforms to specifications set up at the Naval Observatory. As described by Ens. W. R. Bailey, assistant material officer of the Naval Observatory, the requirements outlined for such a substitute were: protection against corrosion; good gripping surface wet or dry; durable, shock resistant material at temperatures from —40 to 170 deg. F. The covering finally selected was a vinyl chloride-acetate copolymer, plasticized sheeting, embossed for good gripping surface. It can be laminated to fabric or applied without fabric, the latter being superior because of greater flexibility. The covering is bonded to the aluminum body by a hot-setting resin adhesive. Seams are heat-sealed by drawing a special pointed hot iron through the seam. Following this operation the surface is pressed with a heated embossing wheel. In some applications, edges of covering must be ground off, which is done after cooling the plastic by refrigeration, or by spraying the surface being ground with cold water. The covering is finished by spraying the entire surface with a vinyl paint and baking at 195 deg. F. Test results of some of the many other materials submitted by the cooperative plastics industry are tabulated (left). Research on molded phenolic resin has been simultaneously carried on to replace aluminum in the binocular bodies and a satisfactory substitute for aluminum is nearing completion.



Carbide and Carbon Chemicals Corporation

Material Tested	Results of Tests on Binocular Bodies
Crackle finish, hard paint	Only thin non-resilient coat applicable. Acceptable cold impact strength.
Crackle finish, sprayed tung oil type	Coating considered too thin, not sufficiently resilient. Thinness of coat would require redesign of binocular body to meet dimensional requirements.
Tung oil lacquer	Chips at low temperature; becomes sticky at high temperatures.
Phenol formaldehyde varnish with sand finish	Sand particles loosened, caused trouble in manufacture.
Artificial leather (cellulose nitrate)	Good at low temperatures, but showed shrinkage at 175 deg. F. Insufficient resistance to abrasion.
Cellulose nitrate sheeting	Too smooth for good grip. Inflammability is undesirable aboard ship.
Cellulose acetate sheeting	Does not emboss well for gripping surface. Crackle finish poor for abrasion.
Hard stippled cellulose acetate butyrate sheeting	Irregular contours undesirable.
Vinyl resin, injection molded	Shrinkage at 140 deg. F.
Vinyl chloride-acetate polymer plasticized sheeting, embossed, laminated to fabric, bonded to body by resin adhesive	First type tested gave satisfactory results, but used strategic types of vinyl resins. New non-strategic compound with same qualities was developed and accepted.
Vinyl chloride acetate polymer plasticized sheeting without fabric back	Same compound as above. Elimination of fabric gives greater flexibility. Embossing made deeper, and method accepted.

Spot-Welding Aids Bearings

Roller retaining rings, which hold the many small rollers in place in the outer races of quill bearings, now are being spot-welded in place by Bantam Bearings Corporation. Not only does the spot-welded assembly simplify machining, but also it results in sturdier, more permanent assembly; the bands cannot snap off. Entire bearing load is carried to solid outer race; retaining rings merely facilitate handling and assembly.

Dimensional Tolerances and Quality Control

J. W. WHITE
Director of Engineering, Bendix Aviation, Ltd.

An engineer's view of the problems involved in the logical application of necessary dimensional tolerances in the manufacture of parts to permit a reasonable latitude for economical production, and at the same time meet customer's specifications and control quality.

ENGINEERS experienced in the manufacture of mechanical devices agree that tolerances are logical and necessary. Absolute measurement is not obtained in either the measuring instrument or in its use, therefore a double set of variations exist in the means used for measurement, and this is aside from the accuracy of the part involved.

The purchaser of the product realizes that if certain dimensions are exceeded, he is deprived of a portion of service he contracted to purchase in the article, and usually insists on inspecting the design and the product to this end.

The manufacturer desires certain tolerances established to prevent arbitrary rejection. The engineering department specifies tolerances to insure a properly functioning product, and the shop insists on the largest limits possible for latitude in processing.

The final drawing with its tolerances established and approved is therefore a contract just as descriptive and binding from an engineering standpoint as any legal document might be. But here the similarity ends because while agreed to in good faith between the contracting parties its execution is dependent upon human frailties, material and conditions beyond the control of either party. Also forecasting a design and the tolerances required is not and never will be an ultimate accomplishment at inception, but rather a relative improvement from an auspicious start.

This shortcoming is well understood by experienced purchasers of automobiles who often express it as follows: "The new model X car is a beauty, but I'm going to wait a few months until they get the 'bugs' out of it."

Specifying proper tolerances is a task more burdensome and difficult than usually conceded. In most new designs the tolerances originally specified are modified later in production after considerable expense in time, labor, material and paper work.

Conversely, manufacturing departments are prone to call for wider tolerances, claiming that those specified are impossible to hold or that they are unnecessary. It is natural for this department to ask for deviations in all complacency and to object to scrap decisions. At this last state the Management also takes a hand because scrap affects profit. Then the inevitable merry-go-round starts of "how high is up"—"how smooth is smooth," and why is one half thousandth over allowed on deviation and a thousandth over not workable and is scrapped. For many parts this is hard to prove. A ruling may be made in favor of manufacturing, then right or wrong down goes the standard of work. Then how about the customer, who bought a certain performance and exerts the right to reject anything less. Truly, the engineer walks a tight rope in a fitful wind.

Some factors encountered by the engineer in setting tolerances are:

1. Compliance and familiarity with

Table I—Tolerances for Cylinder and Piston

Part	Dimension	*Limiting Tolerances		Drawing Tolerances		Permissible for Deviation		Bendix Finish Tolerance Numbers	
		Max.	Min.	Max.	Min.	Above	Below	Nominal	Max. Mi.
Cyl. Bore	*A*	1.0015	0.9990	1.0005	0.9990	0.0010	0.0000	No. 8 — Fin. IE 6 Mi.	8 Mi.
Piston Dia.	*B*	0.9980	0.9945	0.9980	0.9960	0.0000	0.0015	No. 3 — Fin. IE 6 Mi.	10 Mi.
Groove	*C*	0.7530	0.7450	0.7530	0.7470	0.0000	0.0020	No. 3 — Fin. IE 25 Mi.	40 Mi.
Groove	*W*	0.1770	0.1630	0.1730	0.1630	0.0040	0.0000	No. 3 — Fin. IE 25 Mi.	40 Mi.
Ring	In. Dia.	0.7390	0.7290	0.7390	0.7310	0.0000	0.0020	.....	.....
Ring	*D*	0.1450	0.1350	0.1430	0.1350	0.0020	0.0000	.....	.....

* These limiting tolerances may be allowed under deviation only when approved by the engineering department after special consideration.

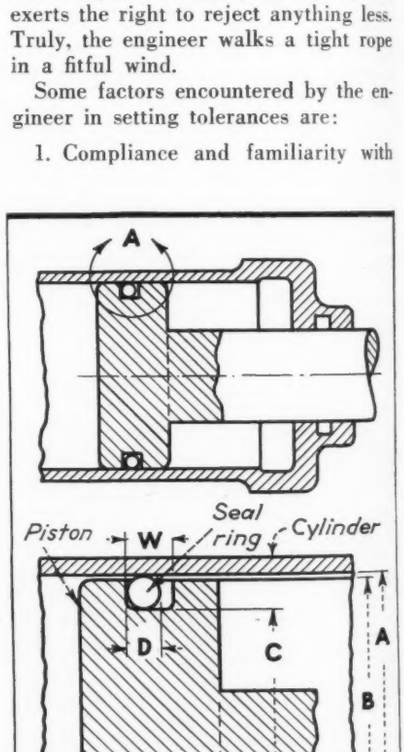


Fig. 1—Typical dimensioning of an aircraft actuating cylinder and piston with "O" ring packing

the purchasing specifications of the buyer, such as Army Air Force specifications and Ordnance specifications.

2. Actual fits and quality of finish required by good performance.

3. Tolerances of purchased parts such as seals, bearings, die-castings, screw machine products and stampings.

4. Accuracy of manufacturing equipment available and method of machining, plating, and finishing.

5. Support of Management.

6. Familiarity with potential shop performance.

7. Knowledge and judgment of the designer and checker.

Assuming that the engineer is versed and knows the correct answers to these problems, that his intent is above reproach, that everyone is trying to maintain tolerances, the question then is, what happens when specified tolerances are exceeded?

Table II—Notation on Drawings for Finish

Unassigned	No. 1 Fin. ———
Smooth machine finish, polish	No. 2 Fin.— 2 Mi.
Smooth machine finish	No. 3 Fin.—25 Mi.
Rough machine finish	No. 4 Fin.–500 Mi.
Finish grind and polish	No. 5 Fin.— 2 Mi.
Finish grind	No. 6 Fin.— 8 Mi.
Rough grind	No. 7 Fin.—10 Mi.
Finish hone, steel	No. 8 Fin.— 6 Mi.
Finish hone, dural	No. 9 Fin.— 2 Mi.
Rough hone, steel	No. 10 Fin.—10 Mi.
Rough hone, dural	No. 11 Fin.—10 Mi.
Sliding packing (rods Chromium Plate)	No. 12 Fin.— 2 Mi.
Unassigned	No. 13 Fin. ———
Unassigned	No. 14 Fin. ———
Stationary packing seal	No. 15 Fin.—16 Mi.

Should a deviation be issued, and if so is it fair to all parties concerned? Will the deviation be accepted and can it be substantiated? Will it help win the War to reject the deviation? Is the part reworkable or is it scrap? Page "Mr. Solomon."

When formulating the answer remember that "an ounce of prevention is worth a pound of cure." In other words, tolerances should be set within the practical range of the shop to perform and still leave some to be granted, "just in case."

Manufacturing departments may argue that all exceeded tolerances passed by deviation is satisfactory work. Often they will maintain that reworked parts are also in this category and that scrap only is chargeable against them.

It may be fairly stated that all three of these conditions are practically classifications of unsatisfactory work graced only by a percentage that will function satisfactorily in the opinion of the engineer. But it is the engineer's problem to plan ahead by tolerance settings so that as many inspection rejections as possible will fall fairly in the deviation range.

If tolerances are set at the widest possible limit everything over is scrap, and if set very close the optimum expectation is all deviations. Obviously, the answer is to be found in the amount of scrap, influenced somewhat by the number of parts reworkable.

An example of this reasoning is given in Fig. 1 which illustrates an aircraft actuating cylinder. The seal ring packing on the piston has a circular cross-section. The bore of the cylinder is honed. The tolerances for the cylinder and piston, shown in Table I, as are issued by the engineering department.

The tolerances listed in Table I in order to obtain low friction, long life, and good sealing are more exact than for chevron seals.

No reference is mentioned in the table regarding concentricity in this example. Such a note should appear where there is a possibility of carelessness or inaccurate machining, also where the concentricity required is closer than standard machining practice. In this example if the grooving and piston diameter were finished in one operation, there is small chance of inaccuracy, but where the groove is finished in a lathe operation and the piston diameter is centerless ground, concentricities must be considered.

A good rule for establishing concentricity is: The total eccentricity of all parts involved (read as full indicator reading) shall not exceed the sum of all clearances involved.

The practice of granting spare tolerance on deviation available in the bore to apply on the piston or in any similar case is illogical and dangerous as a similar grant might be unknowingly issued on the bore. Therefore, the overall tolerance must never be used to apply on a part.

In the example referred to it will be

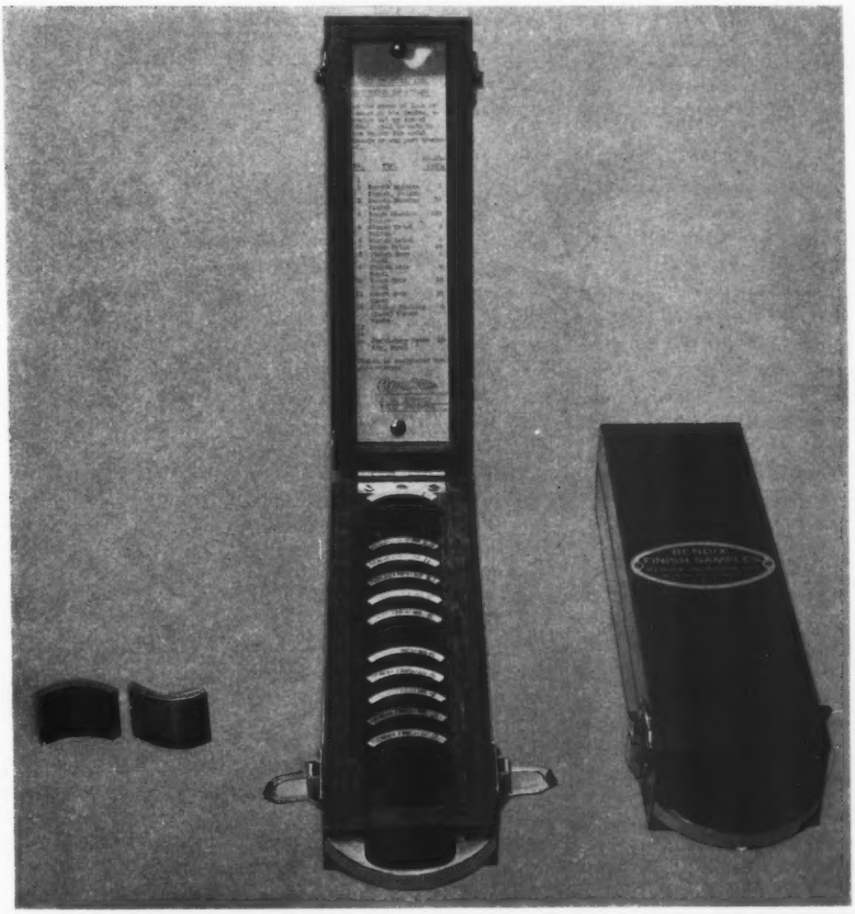


Fig. 2—Reference samples provided by the inspection department are an aid in determining the finish specified by the engineering department

noted that finish specifications are given. These are numbers denoting types of finish for different services. They should be established by experience and adopted by the inspection and manufacturing departments. To aid in determining these finishes, actual samples should be provided by the inspection department. In Fig. 2 is shown a box of typical reference finish samples. Sub-contractors should also be furnished sets and advised what grinding wheels and other manufacturing means are to be used to secure the finish specified. This practice has cut down outside inspection and rejection considerably. In the event of a dispute over the grade of finish a Brush Analyzer should be used for determination of the quality.

Notation on drawings to indicate class of finish should correspond with the respective inspection samples. Table II shows a system of standard finish numbers and their equivalents in microinches.

On drawings the whole notation should be given, such as "stationary packing area" Bendix finish #5, wherever finishes are indicated.

Finish is an important tolerance. In fact a major portion of the dimensional tolerances often include finish tolerances. But to manufacture many parts to a dimensional tolerance and to a finish tolerance at the same time is difficult.

The data listed in Table III is the result of a survey of all deviations requested by one manufacturing department in a one year period based on machine operations.

It was supposed prior to this survey that the greatest number of errors came from drill presses because this class of operators were the least skilled. Part of this belief arose from the fact that drilling operations usually follow after most of the other machine operations are completed and therefore a greater loss was incurred, thus focusing more attention on the operation. The farther down the line an error occurs, the more attention should be devoted to the operator and the setup, otherwise, it's like throwing a tire on the 499th lap.

Because this survey showed that lathes and turrets were the greatest source of trouble (there were no automatics at the time), a further analysis was made on these tools only, with these results

Causes	Percent Deviations	Percent of Parts
Miscellaneous	22	49
Packing areas oversize	20	16

Practically half of the lathe errors were in securing specified finish and dimension simultaneously. This analysis indicated that the alignment and accuracy of these machines should be checked monthly.

Similar problems exist in any industry. They are cited here to show how important it is to follow up the case history of tolerance observance as a guide to engineering and manufacture.

This brings up a discussion of the age old and ever recurring question: Are wider tolerances conducive to less scrap? This is a problem peculiar to each industry.

To find an answer covering a plant manufacturing hydraulic accessories for aircraft, such as hand pumps, pressure regulators, power brake valves, actuating cylinders, accumulators, remote controls, and the usual assortment of check, relief, restrictor, shuttle and four way valves, the dimensions of active products were totaled and classified. The percent of dimensions when classified in four groups, also the percent of engineering deviations requested against them for a period of one year, were found to be

	Percent of Dimensions	Percent of Deviations Requested
Over ± 0.010	16.82	9.05
± 0.010	50.46	28.50
± 0.005	15.41	9.95
Less than ± 0.005	17.31	52.50
Total.....	100	100

About 19 percent of the deviations requested were denied by the engineering department on the basis of design, stress calculations, or predetermined performance.

No exact conclusion from this summary could be reached because no records of the number of units made were taken. But investigation showed that the percentages listed were a fair average of the work in progress. The number of deviations requested was also known. Therefore,

$$\frac{\text{Percent of dimensions}}{100} \times \text{number of deviations} = \text{deviations per unit number of dimensions}$$

By this method it was determined that for every deviation requested for a tolerance over ± 0.010 there was received

1.04 for a tolerance of ± 0.010
1.20 for a tolerance of ± 0.005
5.65 for a tolerance under ± 0.005

Actually most of the dimensions under plus-minus 0.005 were in the plus-minus 0.002 or 0.001 range. The dotted line on Fig. 3 shows these results. A further breakdown of dimensions less than plus-minus 0.005 is shown by the full lines.

This indicates that close tolerances are definitely harder to hold, and that if they are necessary in the product additional precision equipment was required. In this case diamond boring and improved honing units were added.

The author has found that a standardization of tolerances has many advantages. For example, one inspection department formerly had 8 to 12 plug gages for each size bore. This number has been reduced to one or two by standardizing on reamer tolerances wherever possible, and when necessary the tolerances on the male member are closed in where adjustable measuring tools can be used and where machine accuracy can be better controlled. In machining many parts reamers do not give a satisfactory finish but the tolerance is used whether reamed, bored, ground, or lapped, thus obtaining an appreciable saving in time, cost, and inspection.

It will be noted that no mention is made of thread tolerances. In the work here described only number three threads are used and since these limits are fixed, no deviations are asked for or granted.

Table III—Deviations on Machine Operations

Type of Machine	Percent Deviations	Percent of Parts Affected
Grinders	5	2
Lathes and turrets	42	65
Hones	3	3
Threading	11	11
Drilling	27	12
Milling	12	7
	100	100

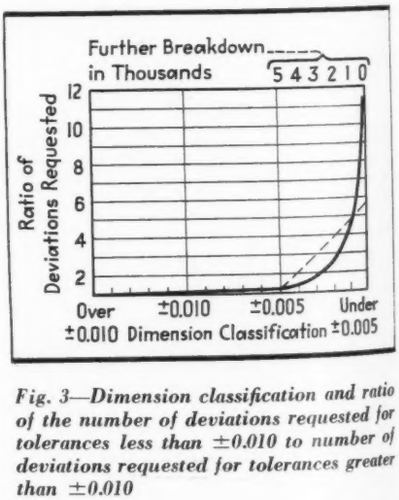
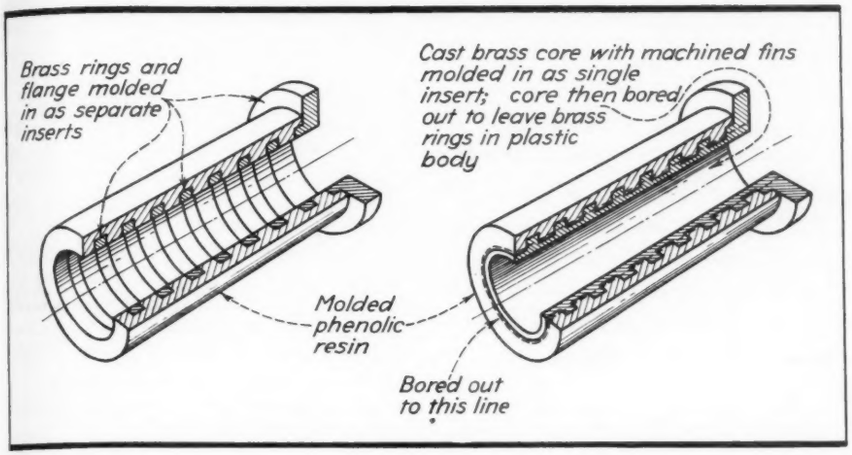
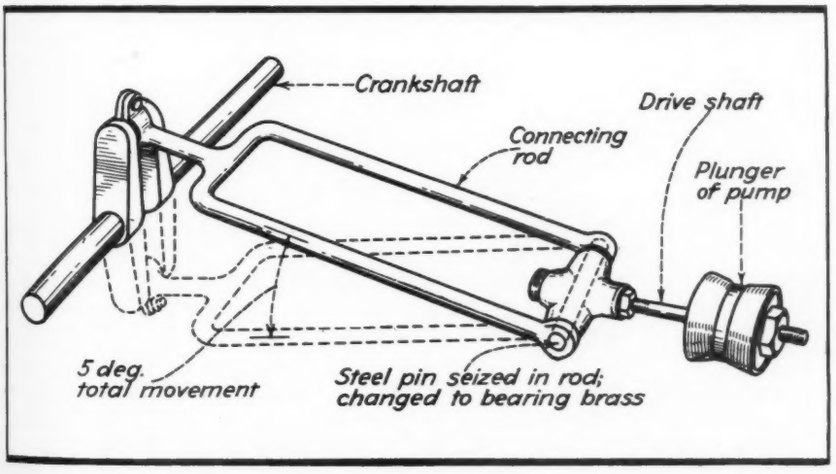


Fig. 3—Dimension classification and ratio of the number of deviations requested for tolerances less than ±0.010 to number of deviations requested for tolerances greater than ±0.010

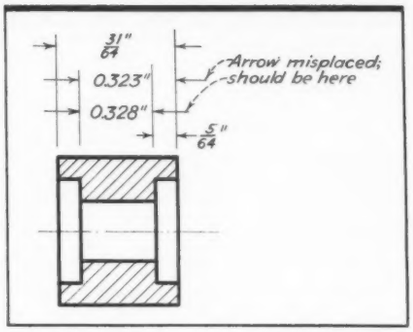
Causes and Cures


Brass rings and flange molded in as separate inserts
Cast brass core with machined fins molded in as single insert; core then bored out to leave brass rings in plastic body
Molded phenolic resin
Bored out to this line

By increasing the amount of metal to be machined away, rejects of this part were reduced to point where overall scrap was actually reduced, with corresponding savings in production time and cost. Finished piece consists of machined brass rings and flange molded in phenolic resin housing. Brass rings must be held to very close tolerances within the plastic—an extremely difficult operation when rings are molded in as separate inserts. By a simple design change, the rings are now machined on a cast brass core which is then inserted as one solid piece in the plastic mold. Finishing operations consist of finishing the flange and boring out the brass core. Rejects are often high on plastic parts with complicated inserts, but many times a simple design change or an extra machining operation such as this can result in tremendous savings. (See also *P.E. July 1942, page 376.*)



Steel pin in crosshead of shallow well electric pump frequently gave trouble by freezing in the cast iron rod bearings. Connecting rod moved through an angle of only 5 deg., and there was not enough movement of the parts to permit adequate lubrication for steel-to-cast-iron bearings. Cure was to substitute a pin made of forgeable bearing brass. This material has a structure of hard crystals imbedded in a soft matrix. The hard crystals absorb pressure, diminish friction, and cause a better distribution of oil between surfaces. The new bearing does not score even if it does seize. After cooling, it can be lubricated and put back into service immediately.



To correct this error involved:

1. Writing, scheduling and routing of Shop Order.
2. Requisitioning of material from stock.
3. Fabrication of material including machining, handling and inspection.
4. Rejection and delivery of parts to salvage.
5. Investigation by salvage survey, decision by Salvage Board, Change Request written, and parts scrapped.
6. Writing of Engineering Order including release complications.
7. Writing Replacement Production Order.
8. Re-requisitioning material from stock.

Apparently minor drafting errors sometimes elude detection and appear as a cause for parts rejection. Conspicuous among these are faulty dimensioning and omission of necessary information on the print. The misplaced arrow shown above was a very minor error indeed, yet a great expense of labor and material was required to correct the error when it occurred in one aircraft company.

CYLINDER HEADS in an experimental model of an air-cooled engine were found to be cracking at the threads. Investigation indicated that a sharp point was present at the roots of the threads. Extreme stress concentrations at these points led to early failure. Trouble was eliminated by specifying proper radius at the roots. It was also necessary to maintain the proper shrink on the lands above the thread so that the heat of the cylinder would not reach the threads in the aluminum, which is weak at high temperatures.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

Surface Roughness Controlled By Use of Aircraft Standard

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Vega Aircraft Corporation

Aimed at clarifying surface roughness designation of machined or ground surfaces for the aircraft industry, a new aircraft standard is described here. The new system enables control of roughness limits by actual measurement. The method of producing a surface is left to the machine shop. Nine roughness numbers, giving "microinch root mean square average roughness," are used with a new checkmark symbol. Principal considerations and applications of the numbers are included with change-over procedure and expected results.

A STANDARD which is aimed at clarifying surface roughness designation for the aircraft industry has been issued as NAS 30 by the National Aircraft Standards Committee. Although primarily intended for machined or ground surfaces, it is applicable to other surfaces as well. The two most significant things about the new system are that roughness limits are controlled by actual measurement of roughness and that the method of producing a surface is left entirely for the machine shop management to determine.

The use of microinch root mean square roughness limits is standardized as the method of controlling surface quality for aircraft manufacturers, and an easily recognizable finish symbol, the check mark shown in Fig. 1, is established to replace the *f* and *G* symbols.

Credit for establishing the use of microinch designation of roughness goes to the Society of Automotive Engineers and the American Society of Mechanical Engineers working under the procedure of the American Standards Association. Through ASA subcommittee B46 they consolidated data on roughness designation, and in 1940 issued a Tentative American Standard. In March of 1941 the Office for Production Management requested standardization of machine-finish in the airframe and aircraft engine industries. The National Aircraft Standards Committee promptly surveyed the machine finish designation systems in use and recommended an adaptation of ASA B46 American Standard for Surface Roughness. First issued as N.A.S.C. Project P-217-1 this standard was issued as NAS 30 on December 31, 1941, after approval by most of the aircraft manufacturers.

Finish Symbol

Fig. 1 shows examples of the use of the symbol with roughness No. 100 and also the dimensions of the check mark. A note may be used to limit roughness of surfaces not otherwise specified. It is intended that the symbol be drawn with a draftsquare or other 60 deg. *V* template. The size is specified to maintain uniformity and good appearance on drawings. In typewritten or printed text it may be represented by a capital *V* or radical sign with raised dash over which the roughness number is placed, for example $\overline{V^{10}}$ or $\overline{\surd^{10}}$, which are read "10 microinch."

Technically, what is meant by a roughness number, such as 10, is "10 microinch root mean square average roughness," a rather cumbersome term which has no application except in research since the roughness measuring instruments automatically read a root mean square average of the height of surface irregularities. This is defined as ASA B46 American Standard for Surface Roughness.

The note "000-000 (for max. and min.)" is applicable only in rare instances which are described below. Where all undesignated surfaces on a drawing are to have a limited roughness, a note may be used such as, "All surfaces not otherwise specified $\overline{\surd^{500}}$"

If all surfaces are to have the same maximum roughness, a note applicable to the whole drawing will suffice:

"All surfaces $\overline{V^{100}}$"

The above notes would apply to machined surfaces as well as non-machined surfaces.

Where the natural roughness of the material is acceptable, no specification is necessary, but this permits coarse sand blasting to remove scale; chipping and sawing to remove fins and sprues. Only the dimensional tolerances on the drawing limit the irregularity of the surface. Therefore, it seems advisable to use a maximum roughness note on practically all drawings. Usually $\overline{\surd^{500}}$ will be the roughest surface tolerable on aircraft parts where natural finish is covered by a note.

Standard Roughness Numbers

In order that standard samples could be made and the roughness of surfaces judged by comparison, it was necessary

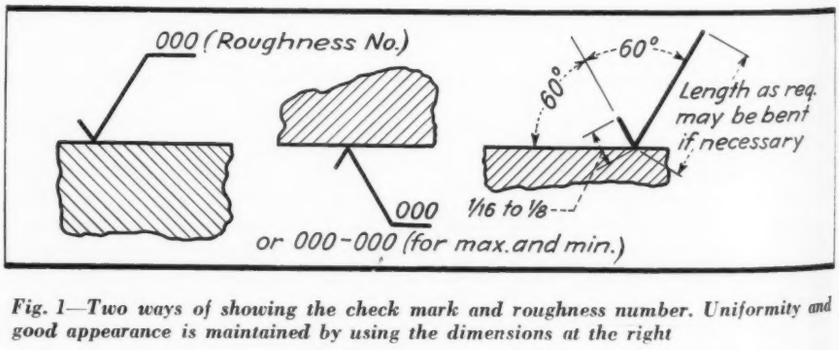


Fig. 1—Two ways of showing the check mark and roughness number. Uniformity and good appearance is maintained by using the dimensions at the right

Aircraft Standard Designations of Roughness

Roughness Number	Definition	Application
500	Rough machine, rough grind, rough file, rough disk grind and similar operations may be used at the discretion of the machine shop.	Cheap finish to produce. Use everywhere possible. Do not use for surfaces in tension. Do not use where notch sensitivity is a factor. Do not use for aluminum alloys or other soft metal.
250	Medium machine, very coarse surface grind, smooth file, smooth disk grind, coarse emery buff and similar operations may be used at the discretion of the machine shop.	Fairly cheap to produce. Use as rough finish for aluminum and other soft alloys. Use on steel and hard alloys where moderate notch sensitivity exists but rough finish is tolerable otherwise. Use for surfaces in moderate tension. Tool marks and scratches will be in evidence.
100	Smooth machine, rough cylindrical grind, medium emery buff, smooth disk grind, coarse surface grind, finish file and similar operations may be used at the discretion of the machine shop.	Fairly cheap for soft metals. Medium cost for steel and cast iron. Coarsest finish allowable for bearing surfaces. Use only where motion is slow and loads are light and infrequent. Use where close fits are required. May be used for all stressed parts except rotating shafts, axles, and parts subject to severe vibration.
40	Very fine machine, carbide or diamond bore, medium surface grind, medium cylindrical grind, smooth emery buff, hand finish with emery cloth, ream, burnish and similar operations may be used at the discretion of the machine shop.	Cheapest finish for hardened steel. Expensive when a lathe, mill, or other machining operation is necessary, but cheap as centerless grind, cylindrical grind, surface grind, etc. May be used for most bearings where motion is not continuous, and loads are light. May be used for rotating shafts and their bushings where loads are light provided direction of scratches is specified to be in direction of motion. May be used for all stressed parts except possibly extreme tension bolts, etc.
20	Fine cylindrical grind, fine surface grind, very smooth emery buff, coarse superfinish, coarse hone, coarse lap, and similar operations may be used at the discretion of machine shop.	Expensive finish except in mass production set-ups where special machines can be used. Proper finish for rapidly rotating shafts, heavily loaded bearings, etc. Required for extreme tension parts such as engine tension bolts. Note: With extreme pressure lubricants 10 micro-inch finish may not carry as much load as a 20 finish, necessitating the use of maximum and minimum roughness limits.
10	Superfinish, microhone, hone, lap and similar processes may be used at the discretion of the machine shop.	An expensive finish to produce. Use only where absolutely necessary. Sometimes required for heavily loaded bearings and journals. Should be used only after coarser finishes are proved to be inadequate. May be used on shafts sliding through packing provided direction of scratches is in direction of motion. Note: Ten and finer finishes may have either dull or bright appearance depending on method used to produce finish. Appearance of surface shall not be considered in judging quality. Either "feel" or roughness measuring instruments shall be used.
5	Suprefinish, microhone, lap and similar processes may be used at the discretion of the machine shop.	A very expensive finish, not to be called out on drawings without approval of production engineering. Required for sliding against packing where direction of finish "grain" or scratches is not in the direction of motion.
2	Superfinish, microhone, lap and similar processes may be used at the discretion of the machine shop.	A very expensive finish, not to be called out on drawings without approval of production engineers.
1	Superfinish, microhone, rouge lap, cloth wheel and tripoli polish and similar processes may be used at the discretion of the machine shop.	A very expensive finish. Not to be called out on drawings without approval of production engineers.

to select a minimum number of standard surface roughness numbers. These were selected in practical steps and are multiples of 10 for all except the two finest surfaces. The range of numbers is great enough to cover airplane requirements. The standard numbers indicate microinches rms maximum allowable roughness, and are limited to numbers 500, 100, 40, 20, 10, 5, and 2. If additional numbers are required, they are to be chosen from preferred numbers listed in the reference specification.

Two additional numbers, 250 and 1, were found to be necessary for engine work by the SAE Aeronautics Division. Both appear in the SAE and ASA standard number lists and are recommended for use where the $\sqrt{}^{100}$ to $\sqrt{}^{500}$ step is too long or a finer finish than $\sqrt{}^{10}$ is required. If their usage is great enough they will eventually be included as standard numbers.

Reference Specification

At present the ASA Proposed American Standard for Surface Roughness is the best available source of information about roughness designation by the microinch method. NAS 30 deviates from it with respect to the symbol and the standard numbers, and should be considered as superseding it in these cases. Coordination of NAS 30, and SAE Aeronautical DRM section on Surface Finish Designation and ASA B46 will eventually take place.

The principal considerations in using NAS 30 are as follows:

1. All roughness numbers are maximum limits, unless maximum and minimum are both given.

2. Drawings will show maximum limit only except for special cases which should be approved by production engineers or others thoroughly familiar with the effects of roughness.

3. Inspectors are expected to reject parts having surfaces even slightly rougher than called for on the blue print (or smoother when maximum and minimum are given).

4. Inspectors will exercise judgment in passing parts having surface defects other than roughness. Roughness is defined as irregularities in a surface re-

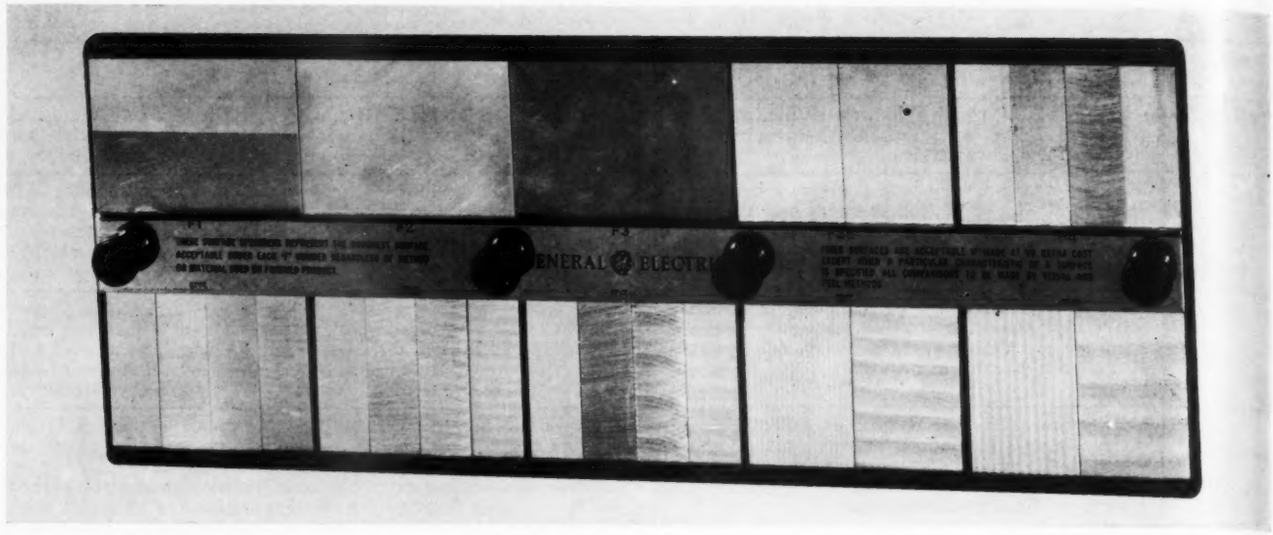


Fig. 2—A set of finished specimens such as this shows the draftsman the appearance of various degrees of finish and aids his selection

curring with a crest to crest measurement of 0.04 in. or less. Waviness, random flaws, or scratches and other defects will be cause for rejection at the discretion of the inspector.

5. Standard roughness numbers are to be used except that 250 and 1 may be permitted if necessary. These numbers are listed in the accompanying table with notes on their usage as applied to aircraft.

Change-Over Procedure

In order to apply some of the advantages of the new finish designation system to old drawings, a conversion table, NAS 31, has been set up to define designations used by aircraft manufacturers on released drawings in terms of the microinch system. When the NAS 31 becomes effective manufacturers will be able to use the "standard sample" method in inspection of parts drawn up under the *f* and *G* system. Also the *f* and *G* will have definite meaning where roughness measuring instruments such as the profilometer and brush analyzer are used to measure the degree of surface finish.

There is one pitfall to be avoided, however. Sometimes it happens that the actual finish that has been applied differs from that called for on the drawing. Because of the reference to the conversion chart, this difference between drawing and practice comes to light. As an example, f_3 may have been called out on the drawing, but some smooth-talking engineer has convinced the shop that this means practically a perfect finish, No. 20 perhaps. On this point NAS 31 requires that:

"Whenever a change in the customary finish is made by the following conversion, the machine shop is obligated to request a review of the drawing in question."

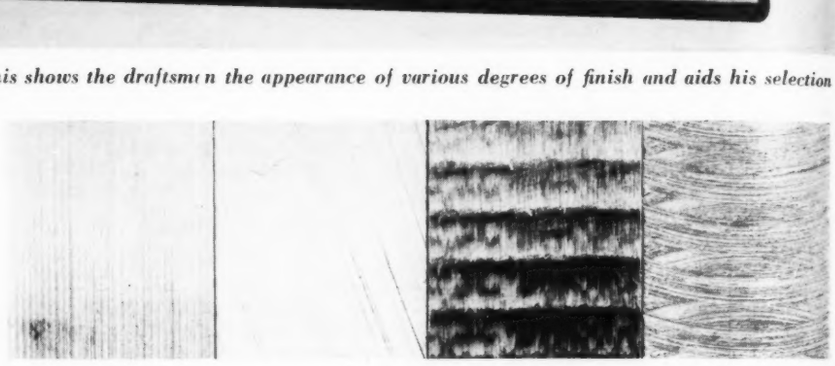


Fig. 3—Surfaces of four sample blocks of 18-8 chrome nickel steel having the same order of magnitude of over-all roughness

In the example cited above, the shop is still obligated to supply the No. 20 finish but can ask that the drawing be reviewed. If the No. 20 finish is necessary, a drawing change must be made. If No. 100 is tolerable, f_3 can remain on the drawing and the shop can increase its production by furnishing the cheaper finish.

Results Expected

Better understanding of the surface finish desired by the designer is the paramount objective of the new standard. The old systems never had any measurable foundation. Rough finishes were permitted but no one knew how rough. Smooth finishes might be called out, but no one could say definitely how smooth a surface was desired. Now standard samples can be made with reasonable accuracy. These can be used for comparative check of surfaces (by feel, preferably). The designer can see and feel a surface, call for it on a drawing, and be sure to get an equal or better surface than any given sample selected.

Secondary results of microinch roughness designation will be collection of more accurate performance data for bearing surfaces and stressed surfaces, and standardization of surfaces required for given functions.

Surface roughness now can be treated as a dimension or specification of a part. It can be called for and measured accurately. A usage can develop which will improve production and improve the product. Manufacturing personnel and inspectors can check a part and come to the same decision on its acceptability from the roughness viewpoint.

Machine shops will find new freedom when blue prints go over to the microinch system. They will be able to choose whatever method of machining they wish so long as they get the required surface smoothness or better. If it is faster to lap than to grind, the shop may lap. If the material contains hard spots and sand, the shop can grind where machine finish was asked for, and a good machinist can turn an aluminum part in a lathe where grind has been previously specified. In extreme cases high quality casting and cold forging can be used to entirely avoid machining where these processes are developed to produce the required smoothness. Of course, the dimensional limits will still have to be met.

How Forging Design Details Affect Cost Estimations

O. A. WHEELON
Methods Analysis Engineer, Douglas Aircraft Company, Inc.

Careful investigation of past forgings costs at Douglas Aircraft Company have resulted in this reasonably accurate method of predetermining relative cost factors. However, the charts and examples presented in this article were based upon normal times where a competitive market existed, and must be corrected for varying economic and geographic situations. They are reliable for comparing costs of forgings of different design and emphasize the effect of design on die costs and production time. See also "Design of Forgings for Speedier Production," in Product Engineering for September and October, 1942.

ACTUAL COSTS of forgings, being influenced by many variables beyond the designer's control, are not easily predetermined. The total cost per piece, like that of any press-worked product, is made up of three main elements: die costs, tooling set-up charges, and material and labor costs per unit of the finished product.

Die costs must be amortized over the sum total of the forgings made. Tooling set-up charges must be allocated over the number of pieces in each production order. Material and labor costs vary with the complexity and size of the part, and are here computed as cost per pound of material in the completed forging. Each of these cost elements can be determined from the data given on the following pages, and are applied in the following computation of cost per piece for a forging of any design:

Die Cost = $\frac{\text{Total cost of die (Fig 2)}}{\text{Total number of parts to be made}}$ \$x.xx

Set-Up Cost = $\frac{\text{Cost of set-up (Fig. 3)}}{\text{Quantity in production order}}$ \$x.xx

Piece Cost = Cost per lb. (Fig. 4) × Est. weight (Material and labor) \$x.xx

Estimated cost per forged part \$x.xx

Die Costs

All else being equal, the size of the forging dictates the dimensions of the die blocks, size and weight of hammer, etc., so that the die costs for most forged shapes vary roughly as the smallest rectangular area in the parting plane which will inclose the part. Fig. 1 shows how to determine this area. This holds true for I-sections, bulbous parts such as valve bodies, round sections, T-sections, moderately deep cone frustums and combinations of these, and also for parts requiring locked dies. See Examples 3, 4, 8, 10, 11, 12, 20 and 26, in Fig. 5 and Fig. 6 on the following pages of this article.

Having determined the minimum rectangular area, approximate die costs can be found from the chart in Fig. 2. Curves on this chart are based upon normal forgings designed according to recommendations given in "Design of Forgings" (P. E. Sept. 1942, p. 524 and Oct. 1942, p. 560). Therefore, these curves must be corrected for those forged parts which necessitate extreme complexity in the die. Some measure of the die costs for difficult-to-make forg-

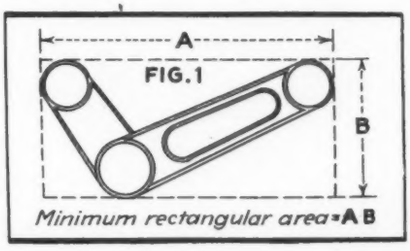


Fig. 1—Die cost for average forgings vary roughly with minimum rectangular area determined as shown here

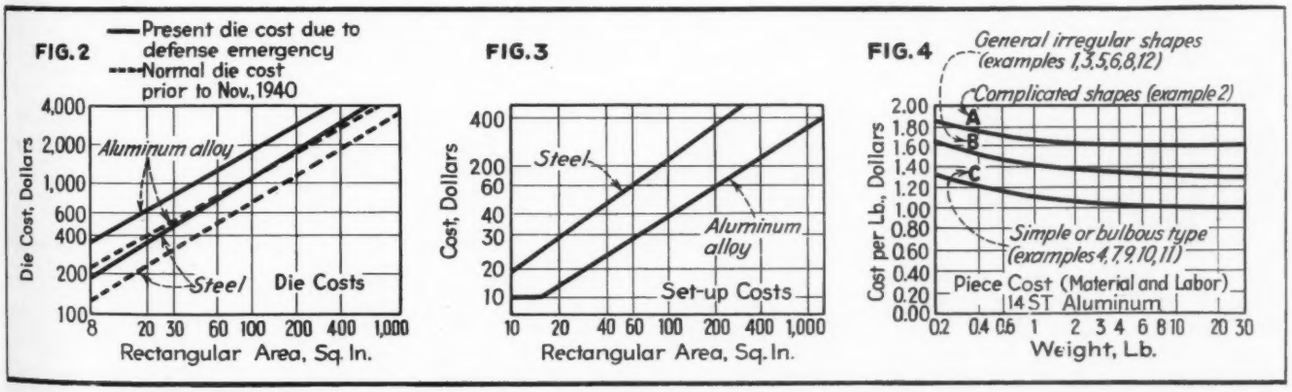


Fig. 2—Chart for determining die costs. This must be corrected for complexity of part (see examples for following pages) and for current economic conditions. Fig. 3—Since set-up costs are only a small part of total costs, this chart is sufficiently accurate for estimation. Fig. 4—Piece cost of material and labor for forgings are here based on cost per pound weight. Use examples on following pages as guide to selection of proper curve. For steel forgings, change scale so costs range from 15 to 40 cents per pound

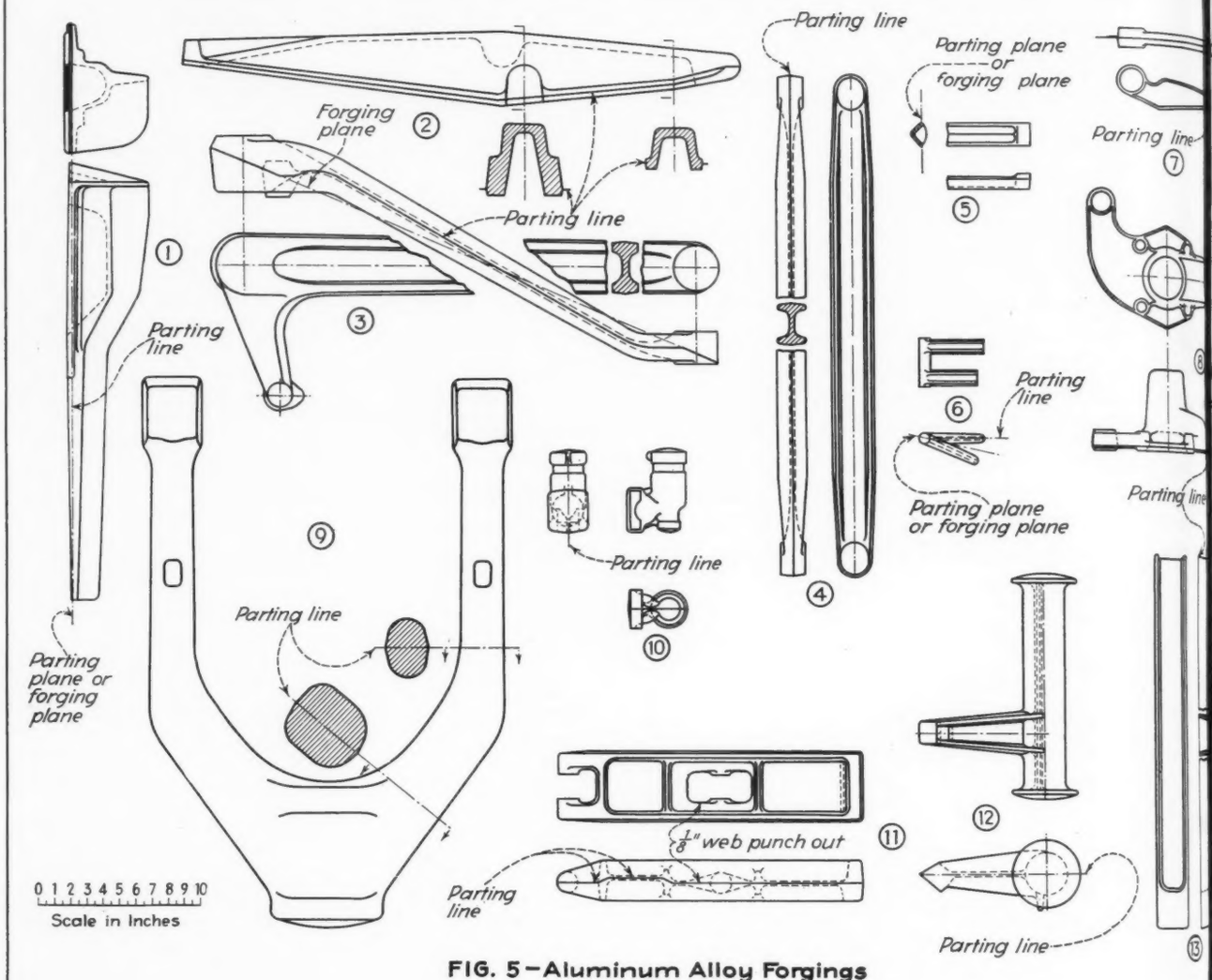


FIG. 5—Aluminum Alloy Forgings

EXAMPLE	1	2	3	4	5	6	7	8	9	10	11	12
Weight (Lb.)	13.5	16.7	19.4	6.2	0.16	0.30	0.91	7.5	98.0	2.2	8.0	9.8
Rect. Area (Sq. In.)	212	154	349	74	5	12	13	66	740	17	83	132
Piece Cost (Fig. 4)	Curve B	Curve A	Curve B	Curve C	Curve B	Curve B	(20% below Curve C)	Curve B	Curve C	Curve C	Curve C	Curve B
Die Cost (% of Normal Fig. 2 Value)	100	350	100	100	170	150	50	100	50	100	100	100

ings can be arrived at by studying the examples given in Fig. 5 and Fig. 6 on these two pages wherein the die costs are indicated as percentages of the costs found from the chart.

A skewed or warped parting plane such as that in Example 6, requires rotating the die blocks during the die sinking, and blending of the parting faces. This increases the cost by about 50 percent.

Dies for a bathtub type forging such as Examples 2 and 5, with a deep male punch and depression in one-half of the die, and a large depression in the other half, require much work in the making. Their cost is proportionately high. They vary from 200 percent of chart value for simple V-type forgings to 300 percent of chart value for complicated inverted U-type.

On the low side of the die cost curves are found those parts which are extremely simple and quite shallow (Example 7) and those in which the actual forging is but a very small proportion of the circumscribed rectangle (Example 9). The cost in each case is about 50 percent of the chart value.

For large-quantity orders of forgings, it is important to design the parts correctly to prolong die life. Formerly, in the aircraft industry, dies were seldom worn out. Now, with much larger quantities of forgings being ordered, dies must be carefully watched for wear during use, since this will be reflected as an increase in die costs. About 10,000 pieces of chromium-molybdenum alloy steel, or 7,500 pieces of aluminum alloy forgings can be made from one set of dies, if the parts are simple and well designed. Poor design of complicated parts may reduce to as low as 10 the number of pieces per die set.

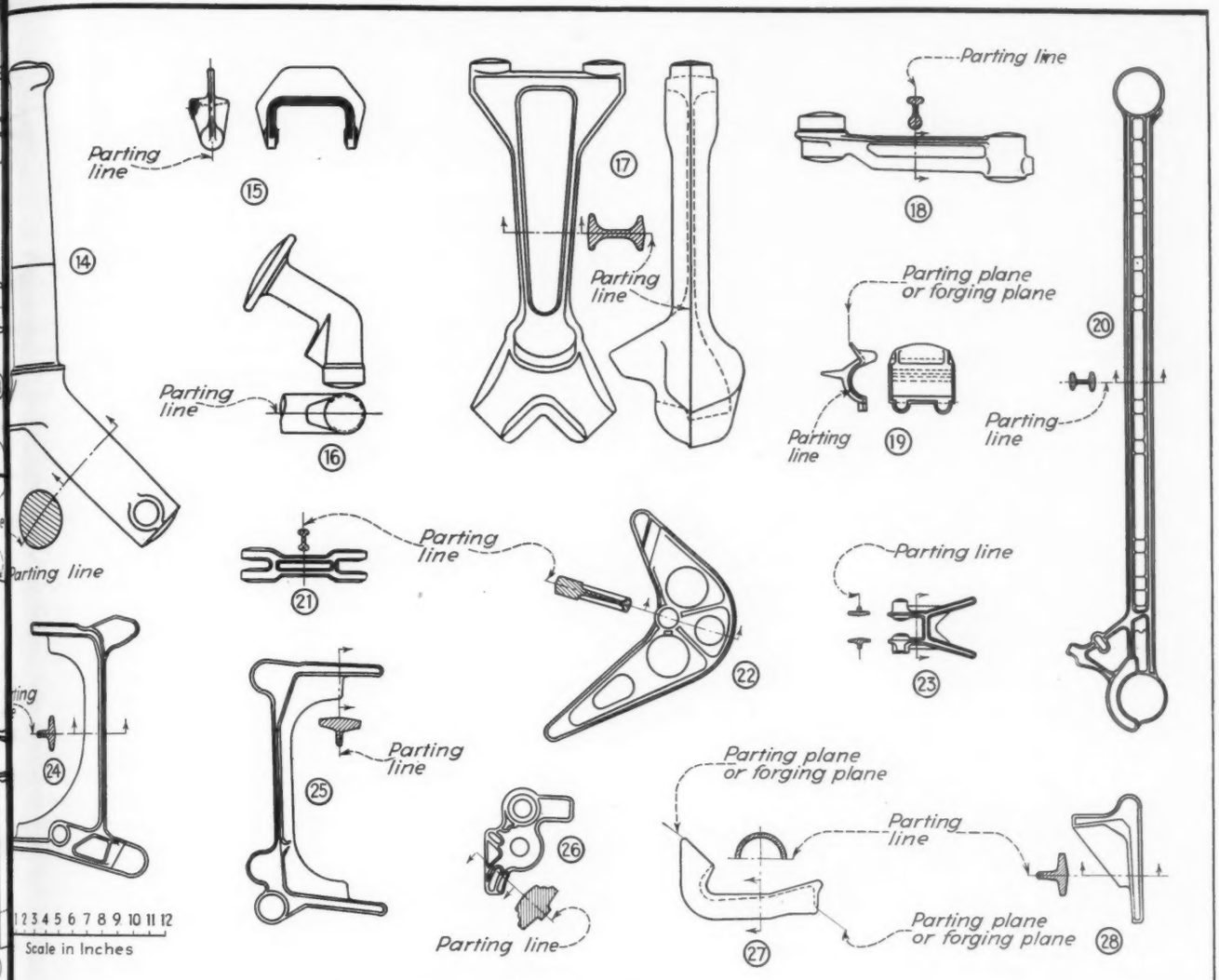


FIG. 6 — Steel Forgings

15	16	17	18	19	20	21	22	23	24	25	26	27	28	EXAMPLE
2.3	13.6	25.9	10.2	2.6	19.3	2.1	8.6	1.9	8.0	17.2	10.3	4.2	5.1	Weight (Lb.)
33	59	227	58	17	234	19	129	19	162	132	34	46	33	Rect. Area (Sq. In.)
Curve B	Curve B	Curve C	Curve B	Curve B	Curve B	Curve B	Curve A	Curve B	Curve A	Curve B	Curve B	Curve B	Curve C	Piece Cost (Fig. 4)
100	70	60	100	160	100	65	60	70	80	75	100	100	70	Die Cost (% of Normal Fig. 2 Value)

Set-Up Costs

Tooling set-up charges cannot be predetermined accurately by simple formulas. However, since the charge is in nearly all cases a relatively small part of the total forging cost, the curve shown in Fig. 3 may be considered sufficiently accurate for general use.

Costs for Material and Labor

Cost per pound of a forged part is a function of the number of successive operations, hammer blows, and re-heats required to produce it, as well as the heat-treating and straightening involved. These are determined by the severity of deformation needed to force the original bar or billet to the peculiar contours of the shape desired. Therefore, compact shallow parts, round bar-like types, bulbous valve bodies and simple generously filleted I-beams will be lowest in price. Protruding ears, severe necking down, thin webs, and similar difficult operations may increase cost by nearly 40 percent.

Chromium-molybdenum alloy steel parts vary in normal times (1940) from 15 cents to 40 cents per pound, depending upon the details mentioned. Aluminum alloy (14ST) costs may be obtained from chart Fig. 4. Curves for high, medium, and low costs depending upon the details of the forged parts are given. The examples on these two pages will serve as a guide in selecting the proper curve of the chart. To use Fig. 4 for steel forgings, change the scale so that the cost curves range from 15 to 40 cents per pound. Costs of A51ST aluminum alloy forgings are approximately 10 percent less than those for 14ST forgings.

Senate Committee Undertakes Patent Reform By Confiscation — II

One of the most drastic proposals for amendment of the patent laws is that which would apply the principle of the antitrust act to activities of patentees and their licensees. Penalties for violation of this principle go far beyond those of other pending bills. This principle and its possibilities are discussed here in the second of a series of articles.

ONE of the pitfalls into which the unwary bill-drafter may unwittingly fall when he tries to legislate for the public good is that in which an attempt to achieve a specific gain is nullified by the very conditions by which it would be achieved.

Such a case is exemplified by Senate Bill 2491, in which proponents of patent reform are attempting to end certain forms of patent abuse by making compulsory licensing part of the United States patent law and by using antitrust prosecution as a weapon to stop the use of patents for market domination.

Compulsory licensing, which was explained last month in PRODUCT ENGINEERING (page 548) attempts to prevent the suppression of patents by refusal to manufacture and sell under them. Provision against this is to be made by forcing the patentee to license his patent if he fails to manufacture under it within a reasonable time.

The whole point of this principle is to free patents, make them available for the public good and to encourage manufacture under them, by forced licensing if necessary.

Patentee Rights Curbed

Then the bill lists four provisions which may not be included in any license, compulsory or otherwise. At least three of these sections, for good and simple reasons, build up in the mind of the patentee, a strong disinclination to license his patent.

Thus the circle is complete. Sections two and three of Senate 2491 force a patentee to manufacture under his grant on a sufficiently large scale to satisfy public demand or to license enough others to do so. Sections four, five, six and nine build up in the patentee's mind a plethora of reasons why he should not do so. Caught in the squeeze of statute law which says bluntly "Thou shalt" and "Thou shalt not," the patentee must make a choice between two alternatives he may consider equally outrageous.

Section 4 of Senate 2491 provides that after effective date of the act, no patent sale, assignment or license may be restricted in any way as to:

1. The extent to which any covered process may be used or the total quantity or value which may be produced under the patent.
2. The price at which any covered commodity may be sold.
3. The purpose for or the manner in which any covered process may be used.
4. The geographical area in which any covered process or commodity may be produced, used or sold.

By prohibiting any restriction on the amount which may be produced, the bill hopes to provide low prices and high production, distribution and consumption. Picking as an example the manufacture of cemented tungsten carbide for machine tool cutting tips, John H. Lewin, assistant U. S. attorney general, told the Senate Patents Committee that agreement between American and German companies limited United States production of tungsten carbide and allowed "fixing and maintaining of unconscionable and prohibitive prices and resale prices, as high as $453 a pound, throughout the United States."

Lewin's point was that had there been no patent pool, and had licenses not been restricted as to output under them, tungsten carbide tools would have been common in price, availability and know-how when the United States defense program started moving two years ago.

Bill Hits at Price Control

The provision against licenses which dictate the price of the products manufactured under them attacks this situation in reverse, and is aimed at preventing low production, distribution and consumption because of a high price dictated by the patentee.

Patent attorneys, however, point out that licenses which control price have often received court approval. The patentee who, unable to fill the demands of an entire market, is forced to license a competitor who might be able to undersell him, might legitimately complain against a provision which prohibits him from establishing a sale price high enough to enable him to stay in business. Certainly, no manufacturer would seek out or welcome such a situation, nor voluntarily enter into it; yet he might be forced to do so under the combined restrictions of compulsory licensing and no price control.

Suppose also that a manufacturer might want to produce under a patent for the "carriage trade," and yet, at the same time, be willing to license another manufacturer to supply the same product in a lower-priced line. Such an arrangement would then be impossible.

It is not hard to guess what the patentee's decision would be in such a case. He would manufacture for the carriage trade, and potential customers who could not meet his price would await the expiration of his patent before they got a chance to use the device.

Of course, such an attitude concerning the manufacture and sale of a necessity of life could be attacked as selfish. Conversely, it would be perfectly feasible when applied to such luxuries as sporting goods or cosmetics.

Inasmuch as the act makes no differentiation between manufacturers of necessities and producers of luxuries, its passage would penalize the latter by the attempt to regulate the former.

Act Works Against Itself

The provision which outlaws limitations on the use to which a patent may be put is aimed at preventing market control in restraint of trade, but its effect can be to discourage the wide use of a product which the compulsory licensing section of Senate 2491 strives to build up.

One of the reasons a patent is issued is to secure for the inventor the right to realize whatever legitimate profit may accrue from his discovery. If his discovery has value in several different fields, and if the patentee be not empowered to retain for himself full rights to realize legitimate profits from any of those fields in which he chooses to operate.

the patentee's incentive to license the discovery, and thereby open himself to competition in his own field, has been crippled or destroyed.

Suppose, for example, an electrical manufacturer is granted a patent on enamelware. If the law prohibits him from licensing another manufacturer to use the patent for kitchenware only, the electrical manufacturer has a valid reason for declining to license his patent at all, and the public has been deprived of a bona fide use of it.

Outlawing geographical limitations in patent sales or licenses also is aimed at preventing market control, and like the other provisions, it can operate against the broadest possible distribution of a commodity manufactured under a patent. Suppose, for example, the patentee be a manufacturer whose only plant is in the eastern United States. He may supply the western and southern demand from his own plant, in which case sizable transportation costs must be added to the price; or he may erect western and southern plants, delaying production under the patent until they are completed and adding the increased overhead charges to the cost of his product; or he may license western and southern manufacturers.

Obviously, the manufacturer's decision would be based on several factors, no pattern of which would be the same for any two producers. But suppose the patentee chose to license manufacturers in other sections of the country. Under this bill, he would have no protection against their invading his market. In such case, the producer might logically be inclined to manufacture at capacity himself and sell nationally.

Infractions Void Patent

To enforce this section, Senate 2491 allows the government to bring an action, which, if sustained after trial without jury, shall result in permanent nullification of all rights under the patent. Only those rights actually held under the patent may be nullified, and they may be revived to whatever extent the conviction is reversed by an appellate court.

The provision seems over-drastic. A simpler provision, which would render any license which violates section four unenforceable in court, would be equally efficient in operation, if such provisions must become law.

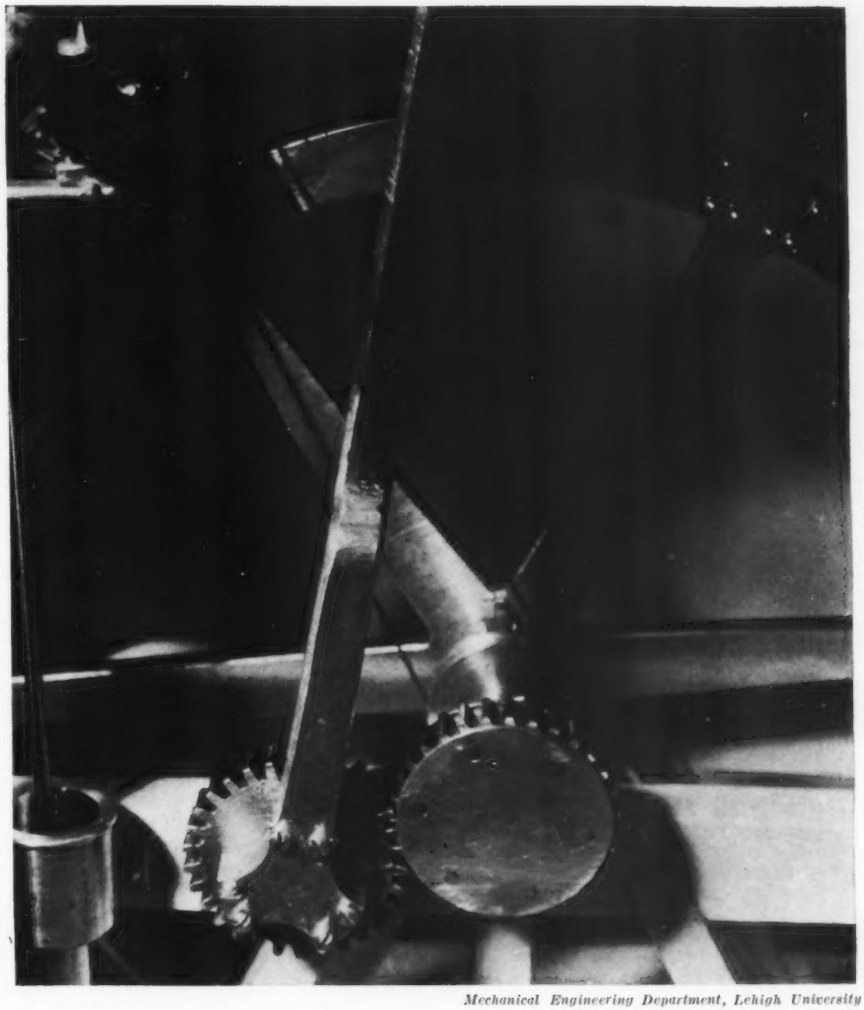
Thurman W. Arnold, assistant U. S. Attorney General and head of the Justice Department's Antitrust Division, is an ardent proponent of patent reform. The most powerful weapon in the hands of reformers, Arnold believes, is withdrawal of patent rights. As might be expected, Arnold approaches the problem from the standpoint of its relation to the antitrust laws.

"As I have often stated," Arnold said, "I believe the remedy lies in the right of the government to cancel any patent privilege if the owner has used it as an instrument of business policy to dominate the market, to fix prices illegally or to destroy independent business. To this end, there must be systematic and intelligent prosecution, certainly more of a penalty than a small fine. With the patent intact, the aggressor still has a weapon of potential power.

"The way to handle the problem is to make the principle of anti-trust laws apply to the patent privilege, just as it does to the privilege of incorporation. If a corporation dominates the market for any commodity, it may be dissolved. If a patent privilege is used for the same domination, it should be cancelled."

In the proposal he submitted to the Senate Patents Committee, Arnold proposed to make all patent sales or conveyances illegal if they were based on any agreement which restricted the price at which the patented commodity could be sold in interstate commerce. The proposal was later introduced in bill form (S.2730) by Scott W. Lucas, Illinois Democrat.

While this provision appears to be less drastic than the corresponding section of Senate 2491, in that it outlaws only price-fixing licenses, the penalty for its violation is considerably more dras-



Mechanical Engineering Department, Lehigh University

The simple sun-and-planet gear shown above was devised by James Watt in the late 1700's to offset a problem posed by English patent laws of the day. Watt was unable to use the crank as a means of delivering power from his reciprocating steam engine to a rotating shaft because his competitor held the crank patent; so he devised the sun-and-planet gear which he patented. Under the compulsory licensing principle now advocated for U. S. patent law, there would have been no incentive for Watt to devise a new method for doing the job, for he could have applied for and forced a compulsory license to use the crank patent. Thus compulsory licensing, in the guise of broadening the use of patents, restricts invention and the development of known processes

tic, for not only are such patent rights cancelled, but the defendant is subject to a $5,000 fine and/or a year in prison. No criminal action may be brought however, on the basis of any act which the patentee outlined in advance to the Attorney General in writing; but advance submission of any such statement does not bar the Attorney General from instituting a civil action to enjoin acts or conduct which he deems to be in violation of this section.

It would be a simple matter for the Senate Patents Committee, moreover, to insert in Arnold's proposal the other three provisions of Senate 2491 which outlaw licenses restricting output, use, or the geographical area in which the patent may be used. If such a provision were to be included in whatever bill the committee finally reports, it would incorporate the wide range of Senate 2491 with the drastic penalties of Arnold's measure, and patentees would be forced, for their own protection, to spend as much time watching their patent operations as in producing under their patents.

Government Becomes Partner

In this matter, as in compulsory licensing, Arnold seeks in effect to have the law make the Justice Department's Antitrust Division a partner of every manufacturer who operates under a patent or a license. The manufacturer would ask his partner and legal adviser, the Justice Department, whether a given course in development of his patent, and whatever business is based on it, would keep him free of criminal prosecution. The Justice Department could approve or reject, according to its interpretation of the law, or could even fail to answer. In any event, if it did not actually throw out the plan, the patentee would be free of criminal prosecution for any action based thereon, at least in Arnold's opinion. The Justice Department at any future time, however, could decide that operations permitted under the plan were unlawful, and seek an injunction to halt them. This whole situation dealing with compulsory licensing was outlined in the last issue of PRODUCT ENGINEERING.

If this provision ever becomes law, it will not make any difference whether the manufacturer whose business is based on a patent right or license wants the Justice Department as a business partner or not. It will be a partner or the manufacturer will be treading a straight and narrow path blocked off with many more obstacles than now encumber it—and the penalty for bumping into one of the new obstacles will be criminal prosecution.

If the manufacturer chooses to go along with the Justice Department as a partner, he will find himself dealing with a partner whose judgments will, for all practical purposes, be directory, not advisory—and a partner who has the privilege of changing his mind at any time, with a civil suit hanging on every whim.

Invalidates Existing Pacts

Senate 2491 also invalidates any sales, conveyances or licensing agreements under contract at the time the bill becomes effective if they contain any provision which limit price, use, output, or the geographical area in which the patent may be used.

It also provides that after effective date of the act, it shall be unlawful to sell, assign, convey or license any patent in any way "which would tend substantially to lessen competition or to create a monopoly, unless such restriction is necessary to promote the progress of science or the useful arts."

As long as the law of the land holds restraint of trade or monopoly to be illegal, there can be no valid complaint against the foregoing principle, which seeks merely to prevent patents from being used in ways which may result in law violations. The section, as it stands, however, is sufficiently broad to allow whatever agency administers the act to go far afield in search of incriminating material against a patentee. The section should be worded so as to limit the agency charged with enforcing it.

A minor section of the Lucas bill would allow the Justice Department to intervene in any court action in which alleged infringement of a patent plays a part. The government would have the right to present evidence and argument on the scope and validity of the patent. This clause would give the government a chance to combat any cheap patent validations which might result from collusive suits or from actions prosecuted or defended only half-heartedly. It could lend strength to the small party lined up in court against a more powerful opponent who might be aiming at market domination, illegal price control or destruction of private business.

It would also give the government an excellent springboard whence antitrust prosecution might be discovered and instituted.

By its very nature, it would mean a vast increase in litigation by the government, and would require a corresponding personnel increase in the Justice Department's antitrust division. Furthermore, government intervention with an antitrust charge could vastly increase legal costs—to the poor inventor and the rich corporation alike.

How much the bill will amount to in this session of Congress is problematical at best. The Seventy-Seventh Congress dies with this year. Within a few days it will face an election, and in its remaining two months, it may have to face such controversial subjects.

Throughout most of the summer, the November election stymied the Patent Committee, few of whose members come up for re-election. If it is in the hands of the House Patent Committee before election, it will get no attention until after the balloting, for every House member comes up for a vote this month.

Also to be considered is the fact that there has been no concerted demand for this legislation and there has been opposition. This will act as a brake, at the very least.

Beyond doubt if the President wants patent reform badly enough to press the issue, he can have it—very possibly in whatever form he asks. The President, however, would be on political-insecure ground if he plumped for immediate and drastic changes in the existing patent structure, for the Patent Planning Commission which he established last Dec. 12 has yet to make its report. The commission includes such personages as Dr. Charles F. Kettering, vice-president of the General Motors Corporation and chairman of the National Inventors Council, and Owen D. Young, former chairman of the board of General Electric Company, and it is unlikely that the President, at so late a season, will rebuff them by demanding immediate action on patent legislation.

Proposals Will Recur

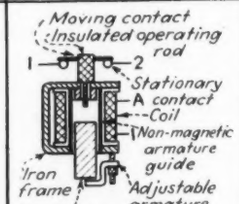
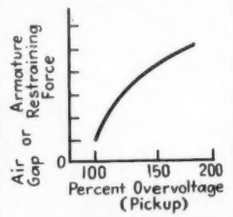
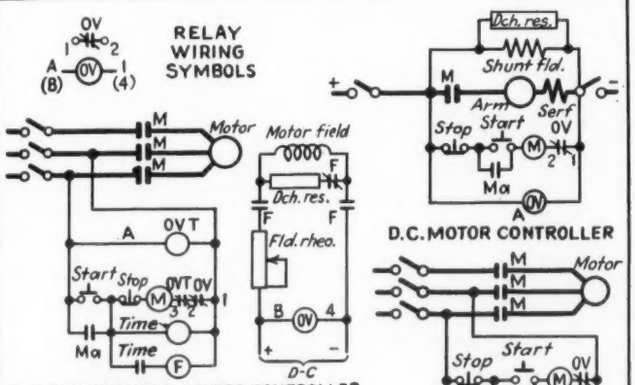
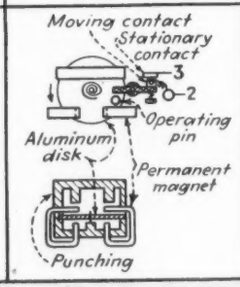
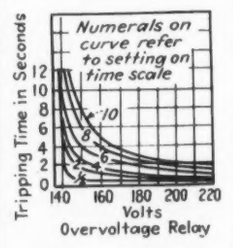
Whatever its fate in this Congress, the possibility of patent reform of one kind or another will undoubtedly remain throughout the present administration and quite possibly into any other administration chosen or dictated by Mr. Roosevelt. Most of the proposals described here sprang from the Temporary National Economic Committee of several years ago. The next Congress will have a year and a half to act before it is threatened by election, it will have the voluminous record compiled by the present Senate Patents Committee, it will be subject to the same urgings that have insisted on patent reform for the past several years.

As long as the New Deal exists, there will be pressure for this type of patent reform. The best defense against it is an unflagging attack which does not permit the contest to go by default. Writing your Congressman is still a good way to attack.

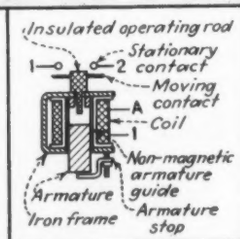
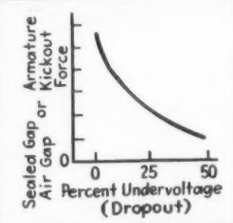
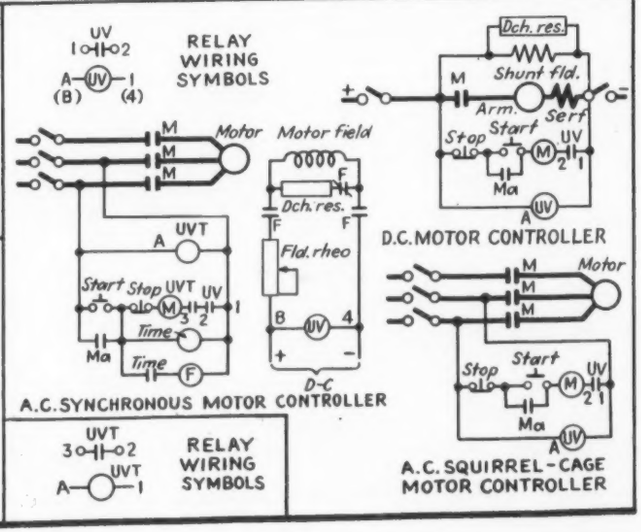
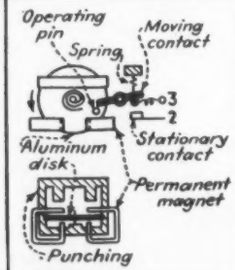
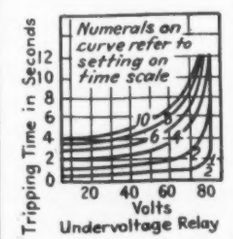
RELAYS CLASSIFIED BY TYPES TO SIMPLIFY THEIR SELECTION—II

R. B. IMMEL *Control Engineer, Westinghouse Electric & Mfg. Company*

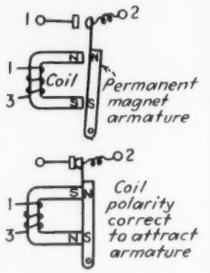
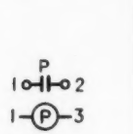
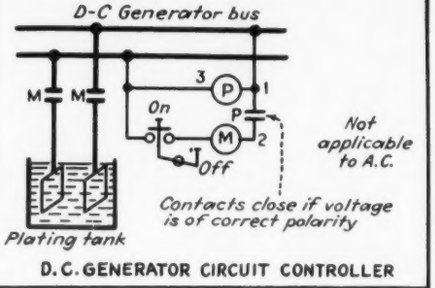
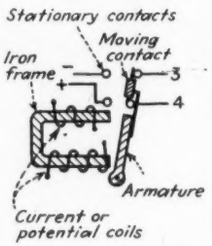
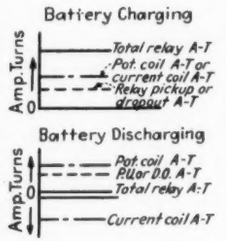
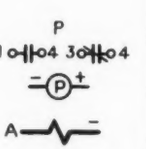
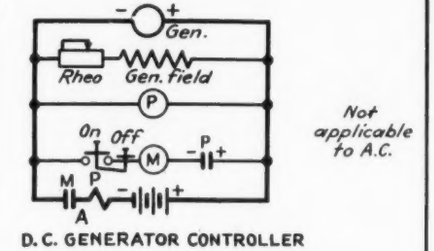
III—OVERVOLTAGE

Type and Application	Mechanical Construction	Principle of Operation	Typical Operating Curves	Typical Applications to Motor Controllers or Generator Circuits
1. Instantaneous Relay. Applied to circuits and equipment where an increase in voltage over normal or rated voltage may damage electrical apparatus or affect output of driven machinery.		At normal voltages magnetic attraction between armature and frame is insufficient to lift armature and open control contacts. At a voltage determined by armature stop setting, armature is lifted to break contact circuit. This voltage depends directly upon the distance between armature and frame core.		
2. Inverse Time Delay Relay. Operates only on sustained peak voltages and will not interrupt service on momentary over-voltages. Voltage relays may be used to interlock a.c. and d.c. power supplies when both are used on the same controller. The induction type of relay is for a.c. application only.		Operates on induction principle for a.c. service only. Main potential coil is below aluminum disk. Upper two windings are energized by auxiliary coil on main pole. Interaction of magnetic fields from these coils produces torque to rotate disk and operate contacts when voltage is high. Field of permanent magnets delays disk rotation.		

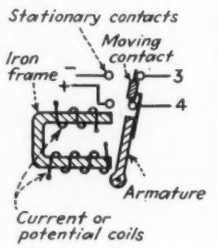
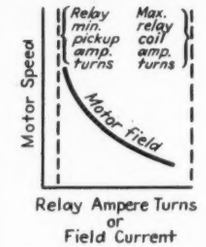
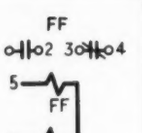
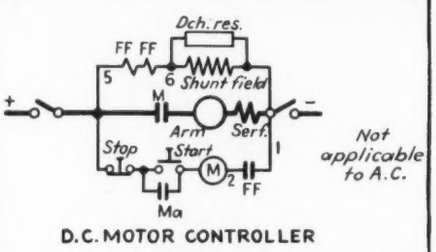
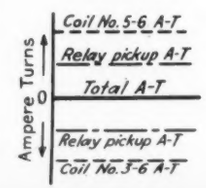
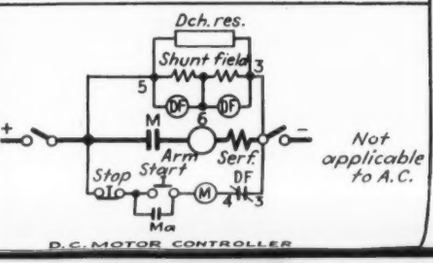
IV—UNDERVOLTAGE

1. Instantaneous Relay. Applied to a.c. or d.c. controllers to prevent motors from operating on reduced voltage, which may affect motor speed or torque characteristics. May be adjusted to release armature, or to "drop out" at a voltage near the "pickup" voltage, at which magnetic force closes armature.		Operation is similar to instantaneous overvoltage relay but has make instead of break control contacts. Since dropout voltage is almost the same as pickup voltage, relay may be used to prevent starting or operating on a predetermined undervoltage.		
2. Inverse Time Delay Induction Relay. This relay guards against sustained undervoltages. Where circuit breakers or latched-in contactors are used, it will de-energize control circuit before voltage becomes too low to operate tripping solenoids of circuit breaker. Control circuits may be arranged so that it is impossible to start a motor unless voltage is correct.		Operation is similar to overvoltage type except for control contact. By means of slide wire resistor, disk torque may be adjusted to close control contacts at a pre-determined voltage and to release them when voltage drops. Rotation of disk, through field of permanent magnets provides inverse time characteristics.		

V—POLARITY CONTROL

Type and Application	Mechanical Construction	Principle of Operation	Typical Operating Curves	Typical Applications to Motor Controllers or Generator Circuits	
1. Directional Relay. In many electro-chemical processes a reversal of current may cause damage even if the current is small or of short duration. This relay operates on voltage and can prevent energization of a load circuit if its polarity is incorrect. The relay may also be used to shut down a generator if polarity is incorrect.		Direction of current flow in coil either assists or neutralizes flux from permanent magnet. Armature is held either in attracted or repelled position depending upon coil polarity.			
2. Current and Voltage Relay. An ordinary voltage or current relay, upon which two coils may be installed, may be used for current reversal protection. Applied to a battery charging circuit, it prevents battery discharge through generator if generator stops accidentally.		Ampere turns produced by potential coil are sufficient to operate relay. Ampere turns produced by charging current through current coil also assist in holding relay closed. If generator voltage becomes lower than battery voltage, current reverses and tends to drive generator. Reversal of current in series coil neutralizes magnetic effect of potential coil and allows relay to open.			

VI—FIELD PROTECTION

1. Field Failure Current Relay. Prevents starting or running of a d.c. motor with open field circuit since coil or coils are connected in series with motor field. On adjustable speed motors coils must be selected so that relay will operate on minimum field current and coils will not overheat on maximum field current. 2. Differential Voltage Relay. A field failure current relay will not provide protection when all or part of the field is shorted out because short-circuit current may still cause the current relay to hold circuit closed. A voltage relay used as differential relay protects against short circuit and field loss resulting from winding failure.		Current passing through field, which is in series with coils, operates relay so that control circuit is effective. If field current fails, relay is deenergized and control circuit opens.			
Voltage coils are connected across identical sections of field in such manner that magnetic force from one coil neutralizes that from the other. Armature will not move while this condition exists. If this balance is destroyed by winding failure or short-circuit, relay operates to stop motor.					

used as differential relay protects against short circuit and field loss resulting from winding failure.

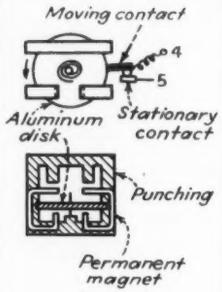
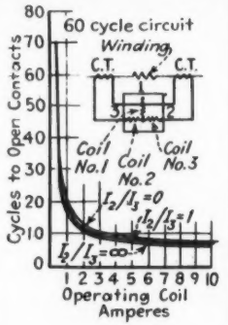
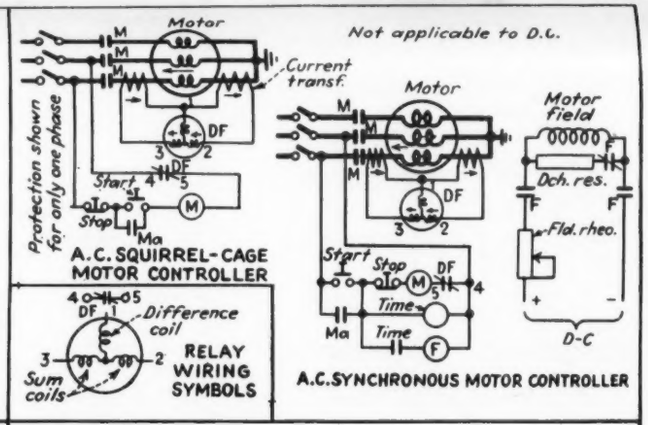
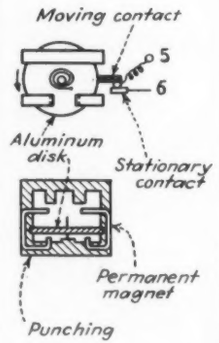
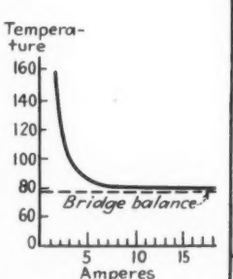
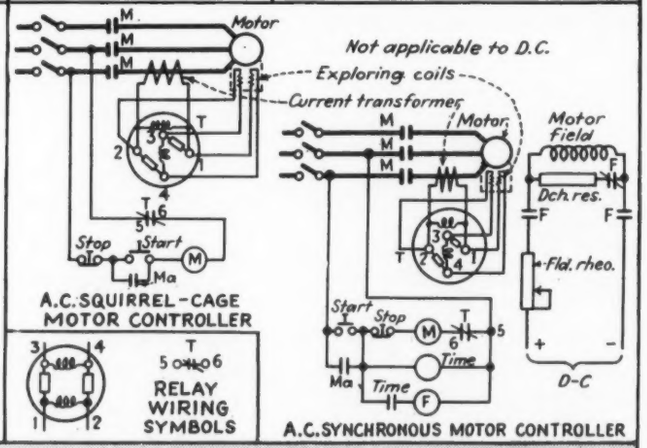
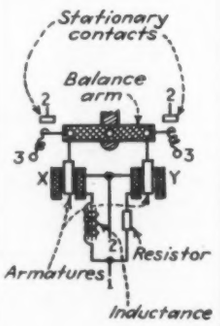
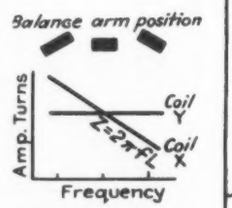
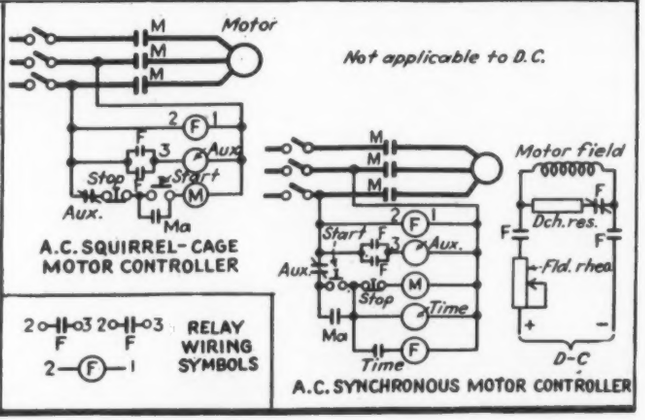
exists. If this balance is destroyed by winding failure or short-circuit, relay operates to stop motor.

Relay pickup A-T
Coil No. 3-6 A-T

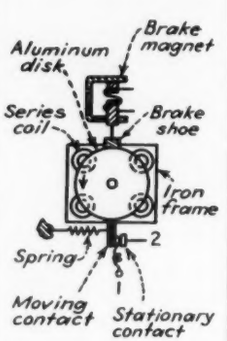
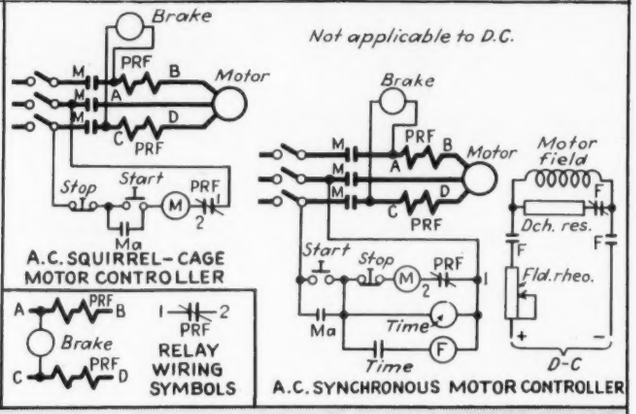
RELAY WIRING SYMBOLS

to A.C.

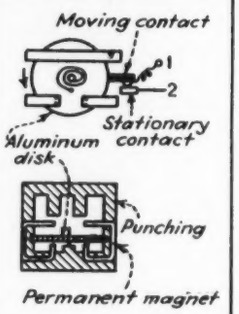
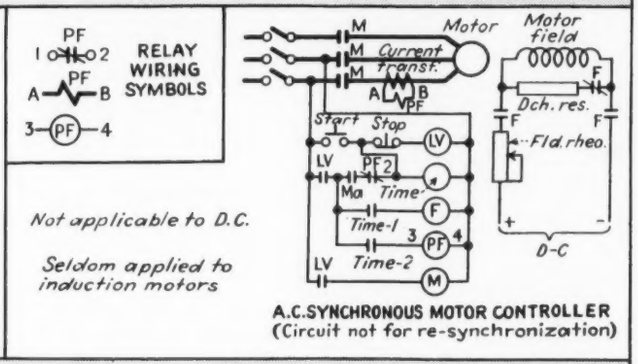
D.C. MOTOR CONTROLLER

3. Ratio Differential Relay. Protects against internal faults on a.c. apparatus by balancing current entering the apparatus against the current leaving it. Each phase has a relay. Leakage of current from one phase to another or to ground can be detected and the apparatus disconnected before serious damage occurs. Relays operate only on unbalance in the machine itself; not on system faults.		A field proportional to currents in sum coils reacts with field proportional to their difference. Resultant field tends to rotate disk. Quadrature flux is supplied to upper poles by transformer windings on each of lower poles. Current through sum coils tends to hold contacts closed. A current that is proportional to load current through difference coil will open contacts. Current through difference coil is the difference between input and output currents.		
4. Winding Temperature Relay. Protects against excess heat in windings of a.c. motors. Before relay operates to stop a motor, (1) winding temperature must exceed calibrated value, (2) line current must be above normal, and (3) these two conditions must exist for a predetermined time. Relay will not operate on transient overload.		Operates on wheatstone bridge principle. Two fixed resistances in relay serve as two arms of bridge, while two copper exploring coils embedded in winding serve for other two arms. At normal operating temperature, no current flows in upper winding. If motor winding becomes overheated, bridge balance is destroyed and current flows in relay upper winding. Field thus produced by upper winding reacts with that of lower winding and produces a torque to rotate disk to stop motor.		
VII—FREQUENCY CONTROL				
1. Frequency Relay. Prevents operation of induction or synchronous motor on higher or lower than normal frequency, which is proportional to motor speed.		As long as frequency for which relay is set remains constant, balance arm does not move. A change in frequency changes impedance of inductance coil and destroys magnetic balance, since any frequency change has relatively little effect on resistor circuit.		

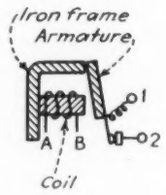
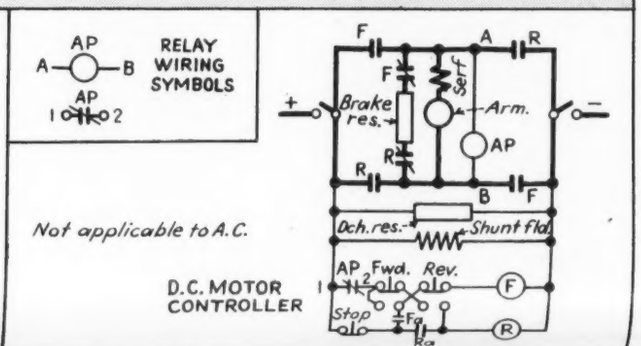
VIII—PHASE REVERSAL OR FAILURE

Type and Application	Mechanical Construction	Principle of Operation	Typical Operating Curves	Typical Applications to Motor Controllers or Generator Circuits
1. Phase Reversal and Phase Failure Relay. Prevents (1) change in direction of a.c. motor rotation and (2) operation on single phase. Reversal of phase rotation in a polyphase system reverses motor rotation. Failure of one phase would compel a motor to operate on single phase, with probable excess current and resultant overheating.		Operates on same principle as two-phase induction motor. Eddy currents induced into aluminum disk react with rotating field to produce a torque. Disk tends to rotate and holds contacts closed if line phase rotation is correct. If a line phase opens when motor is running, spring force opens relay contact because single phase develops no torque. If phases become reversed, disk rotates to stop motor. If phase rotation is altered, a motor being started will run only an instant until relay operates.		

IX—POWER FACTOR

1. Power Factor Relay. Opens circuit and stops motor or resynchronizes synchronous motor when power factor of a.c. circuit drops below predetermined value. Principal application is to synchronous motor controllers. Provision must be made on controller to make relay ineffective during starting period as power factor is very low.		When voltage and current are in phase, their magnetic fields produce no torque to rotate aluminum disk. Torque from the two fields is proportional to their product times the sine of the angle between them. Relay may be calibrated to operate at 60% lagging power factor.		

X—ANTI-PLUGGING

1. Anti-Plugging Voltage Relay. Prevents closing contacts in motor reversing controllers to reverse direction of d.c. motor rotation until the rotating armature has been braked down to safe speed. On high inertia loads anti-plugging control prevents excessive strain on motor and driven machinery. Relay is so designed that it will not close its contacts until armature of motor has practically stopped rotating.		Relay has high pickup ampere-turn and low dropout ampere-turn characteristic. When motor is connected to normal voltage, relay contacts are open. They remain open until generated armature voltage falls below a critical value. These characteristics are given by a large armature gap and a small permanent gap in relay magnetic circuit.		

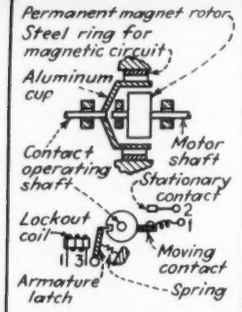
XI—PLUGGING

1. Zero Speed or Plugging Relay. Prevents reversing motor from rest until armature has come to rest. Relay is connected across armature of motor. Relay contacts are open when motor is at rest. Relay contacts close when motor is connected to reverse direction of rotation. Relay contacts open when motor armature comes to rest.		Motor driven permanent mag-		

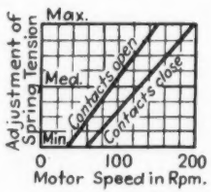
its contacts until armature of motor has practically stopped rotating.

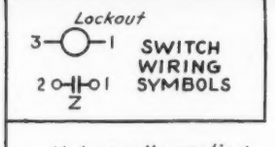
XI—PLUGGING

1. Zero Speed or Plugging Switch. Used with reversing linestarter to stop a.c. motor quickly after pushing stop button. When rated speed of coasting motor is "plugged" down to about 40 r.p.m. by application of a voltage of such phase rotation as to produce an opposing torque, control switch opens and opposing voltage is removed. A typical device with the construction illustrated requires about 1/20 hp. when driven at 1,800 r.p.m.



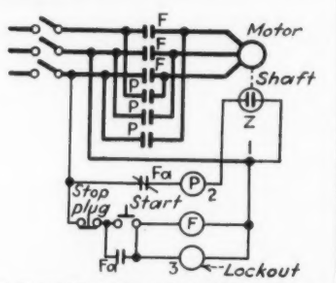
Motor-driven permanent magnet produces rotating field which induces eddy currents in aluminum cup. Field and current produce torque which rotates cup and closes its contacts. Cup is held in open contact position until speed or torque is sufficient to overcome restraining spring. Magnetic latch prevents accidental energization of control if shaft is rotated by hand. Closing and opening characteristics may be adjusted by a spring.





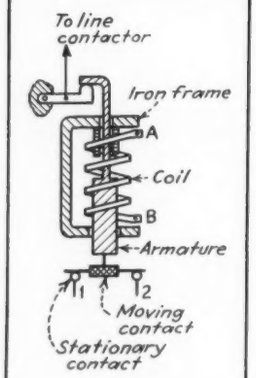
Not usually applied to D.C. motors

Seldom applied to synchronous motor control

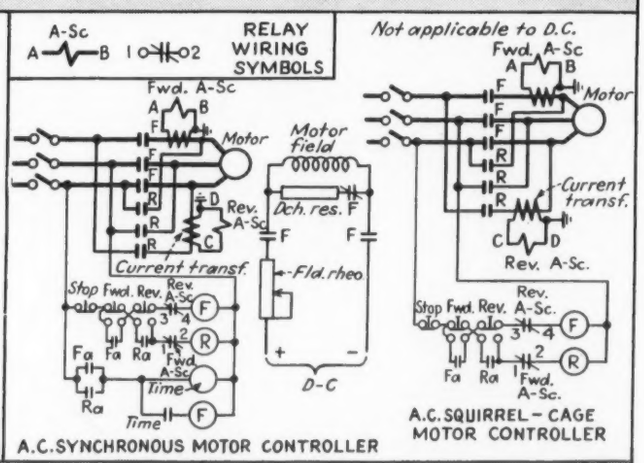


XII—SHORT CIRCUIT

1. Current Relay. Prevents closing of opposite direction contacts as long as arc exists on the opened contacts of motor reversing controller. On high voltage a.c. circuits, such as 2,300 volts or higher, the arcs are more difficult to extinguish when the line contactor opens. Should opposite direction contactor be closed while arc remains on other contactor a short-circuit will occur.

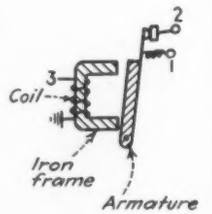


Armature and moving contact mechanisms are mechanically connected to line contactor so that armature is lifted and relay contacts are opened each time contactor is operated. When contactor opens, relay armature is released and is mechanically free to fall but is held up magnetically as long as any current flows. Arc must be extinguished before relay contacts reclose.

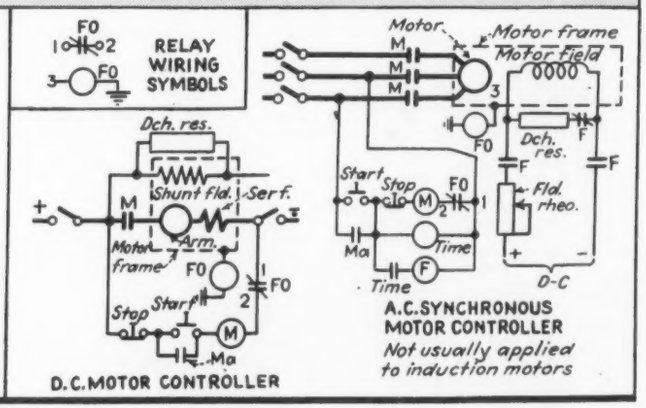


XIII—FLASHOVER

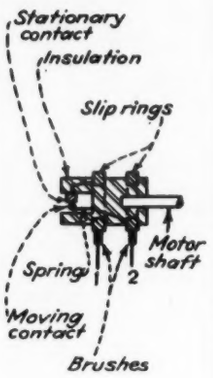
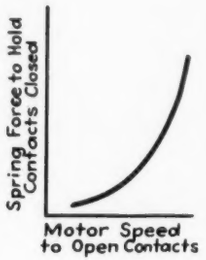
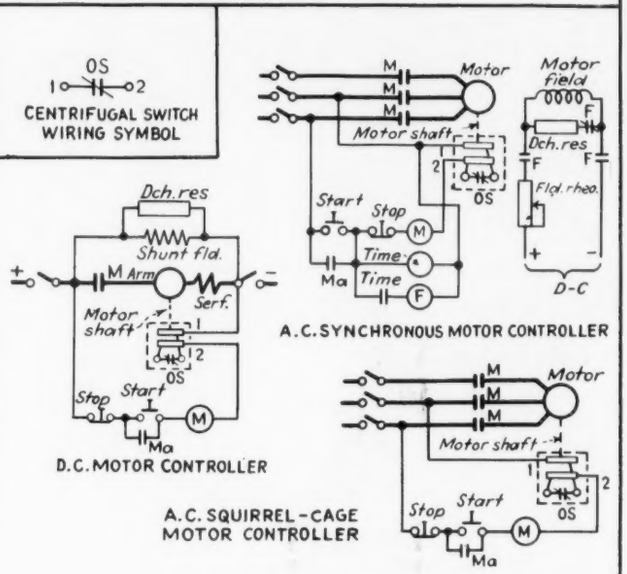
1. Voltage Relay. Disconnects motor from line if flashover occurs from commutator or slip rings to ground. Usually operates instantaneously and fast enough to prevent operation of the system protective relays and to avoid any great damage to motor.



Flash-overs usually occur between insulated circuits and frame of machine. Relay operates to deenergize motor power circuit when its voltage coil, which is connected to ground and machine frame, carries current from flashover.



XIV—OVERSPEED

Type and Application	Mechanical Construction	Principle of Operation	Typical Operating Curves	Typical Applications to Motor Controllers or Generator Circuits
1. Centrifugal Switch. Prevents overspeed of motor or may be used as a governor. Actuates control equipment to maintain constant speed of rotation. Often used to maintain constant speed on universal or series motors applied to business machines.		Contacts remain closed as long as spring pressure exceeds centrifugal force when device is rotated. Speed at which contacts open may be adjusted by spring or by varying mass of moving contact. Slip rings connect rotating mechanism to circuit.		

XV—BEARING TEMPERATURE

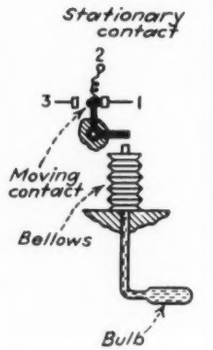
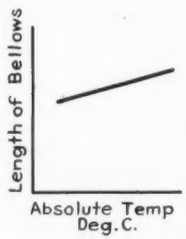
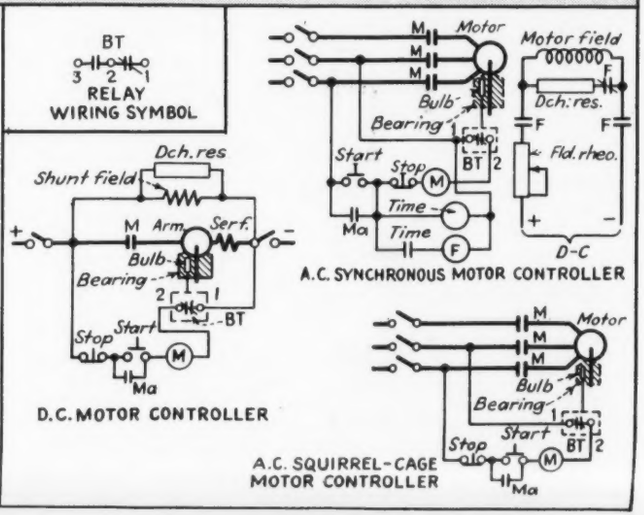
1. Thermostatic Relay. Protects bearings, resistors, cables, transformers, etc. against overheating. Thermostatic bulb may be located in material or in contact with material to be protected. Where equipment has supervision, relay usually actuates a signal to prevent unnecessary shut downs. Where supervision is not maintained, relay may be used to stop motors.		When temperature of material to be protected rises, liquid in contacting bulb volatizes and creates pressure which expands bellows operating toggle mechanism.		

Fig. 1—Subassembly set-up on photostating frame being exposed to sensitized paper in machine. Note border and title block

Photostat-Tracings Save Drafting Room Time

LESTER C. JONES
Engineer, Lockheed Aircraft Corporation

How routine drafting operations can be eliminated in the engineering department by the use of a photographic method to produce tracings from which working blueprints can be made. Advantages and limitations are described, also the procedure for making various drawings.

IN THIS AGE of inventions for winning the war, it is logical to expect a rapid improvement in many conventional methods and processes even though they may be recent developments. This is especially true in photographic methods being utilized to speed production in engineering departments. The latest addition to this field is the "Photostat-Tracing" now being employed at the Lockheed Aircraft Corporation in addition to the new "Photo-Tracing" process.

Photostat reproduction as it is generally known today is nothing more than a speedy photographic method of securing a cheap reproduction. This method has been in use for many years.

Photostat-tracings and the usual photostat reproductions are not identical, for instead of photostating pictures or straight line drawings, objects are shot directly, thereby producing a photostat which contains a negative reflection of the object photostated upon a white background. If the object is placed on a negative sheet with black background and white borderline and title block, a photostat-tracing is received from the machine which needs only the bill of material and pencilled notes to be added to obtain a tracing from which working blueprints can then be made.

The steps followed in securing a photostat-tracing are as follows: 1. Set up the part or object on photostating frame in the best position for desired

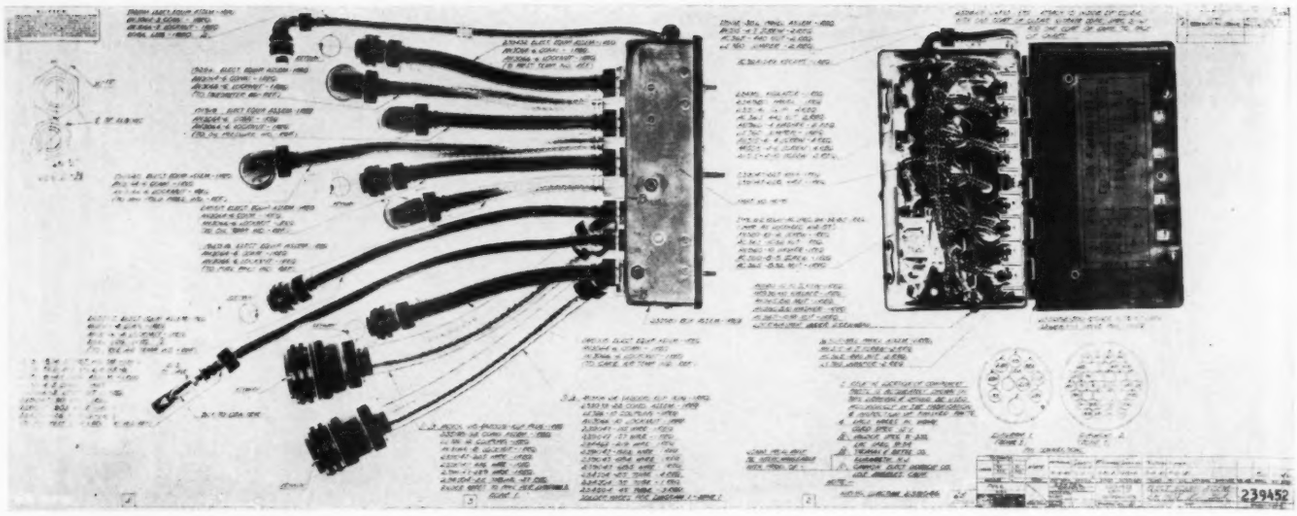


Fig. 2—Photostat-tracing showing two views of an electrical assembly. This tracing was made in two exposures

results. Improvised jigs or fixtures may be necessary to hold the object. Insert under the part a photostat negative of title block which has been previously made. This negative may be used indefinitely. 2. Focus and adjust photostat machine. 3. Make exposure. 4. Wind exposed sensitized paper into box in dark room. 5. Process exposed photostat. 6. Dry. 7. Photostat work is recorded (no files for negatives or positives). 8. Photostat-tracing (dried sensitized paper) is brought to engineering department for completion in pencil. The shortest elapsed time is approximately twenty minutes.

It will be noted that the method of making a photostat-tracing is similar to making a "Photo-Tracing" as described in an article by the author in PRODUCT ENGINEERING, January 1942, the difference being the elimination of the intermediate steps of making the mask and negatives to be used later in enlarging on the sensitized cloth. In the photostat process the object is exposed directly on the sensitized paper, the exposure is developed and dried and is then ready for use, thereby reducing cost and saving time.

At the time of this writing, there are certain limitations encountered in the use of photostat-tracings, therefore it has not replaced photo-tracing in its entirety. Each single exposure on the photostat machine is limited to an 18 x 24 in. size. If a larger exposure is needed, a larger size photostat machine must be used, or the photo-tracing process which will handle an exposure up to a 40 x 72 in. size is employed. In addition, it is believed possible to splice two or more exposures by photo-tracing with a reasonable amount of accuracy, but as yet this accuracy is still to be developed in the photostat process.

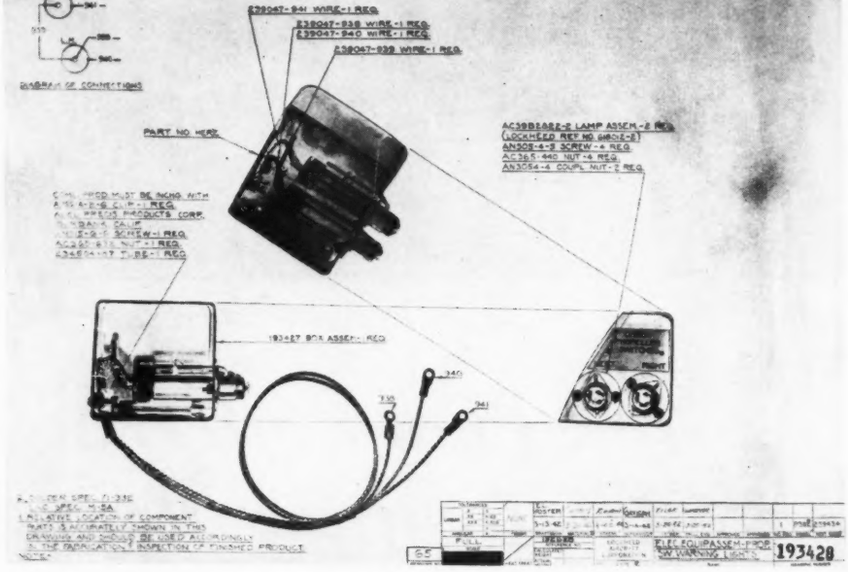


Fig. 3—Three views of an assembly made at one setting, this is a triple exposure

If it is necessary to produce a drawing that will allow breaks in order to accommodate a long assembly, it is possible to produce a photostat-tracing of it, but the object must not be wider than the size of the roll of sensitized paper. The drawing will show "breaks" wherever the paper was rolled for the next exposure. This is often standard drafting practice on large drawings.

Two views of an object can be made on a single drawing if the object is not wider than the width of the sensitized paper or longer than a single exposure. After one view is taken, the paper can be wound to the position for the second view. This view, after being oriented with the position of the previous view, may then be photostated. The developed

drawing will then show two views of the same object as shown in Fig. 2. Care must be taken to use the same amount of exposure for both views so that the tracing will be evenly developed.

Location of the first view may be made with the aid of a ground glass, but the second view must be aligned by judgment of the photostat machine operator. This should be done with the assistance of an engineer or draftsman, as it is necessary that this type of a tracing be in accordance with standard drafting practice.

More than one view can also be made at one setting as shown in Fig. 3. In reality, it is then a double or triple exposure, depending on the number of views needed. Since the rest of the drawing will be overexposed, not more than a triple exposure is recommended.

This is accomplished in the following way: 1. Place object in desired position and make exposure. 2. Remove object from first position and place it in position for second view and make exposure. (Do not wind sensitized paper.) 3. Remove object and place it in desired position for third view and make exposure. 4. Process the tracing. At this time, a gray background on the tracing may be noted, caused by the excessive exposure of the background needed for all three views. The blackground can be "bleached" with a chemical prepared for this work. With careful bleaching, the tracing will have three distinct views on a clear white background, which will make a clearer working blueprint. After drying, the tracing is then ready for engineering use.

If enough parts are available it is possible to eliminate steps (2) and (3) by using one part for each view and exposing them all at once.

When necessary it is possible to make a new tracing similar to an old tracing with a few minor changes. A quick and economical reproduction can be made of any photostat tracing by merely making a photostat negative of the existing drawing. By removing (or "opaqueing") the undesirable portions and then making a positive from the negative, a new photostat-tracing is produced. By the addition of a little pencil work, a new drawing is made. After going through so many photographic steps, the image will not be as clear as the original but workable blueprints can be made. When a new drawing is required of a photostat-tracing, this method has been found desirable. If a better drawing is desired after the first assembly is made, a new photostat-tracing can be made to replace the existing drawing.

Another use of photostat-tracing is in the reproduction of installation drawings. The procedure is as follows: A photograph is taken of a mockup installation. As many photographic views are taken as may be needed for one drawing. An enlargement is made of the photograph to the size desired, which can then be exposed in the standard method of photostating. If more than one picture is desired on one tracing, as shown in Fig. 4, the picture can be exposed in progression without cutting the paper after each exposure. A total length of not more than 8 ft. is desirable; drawings longer than that are difficult to develop. A sufficient amount of space should be left on any drawing for the addition of bills of material, notes and titleblock.

The photostat-drawing can be used also to reproduce present drawings to a smaller size for reference and shop use. Blueprints can be made from reduced photostat-drawings. This method is used in the Lockheed Production Illustration Department. After the original sketch is made to full or half scale, it is reduced by photostating and these reductions, or blueprints from them, released to the shop.

In order to secure a readable blueprint from a photostat-tracing, it is necessary to use a thin photostat paper, since the heavier the texture of the paper the slower the blueprint machine must run, and it is desirable to blueprint at a speed much slower than that needed for the average tracing.

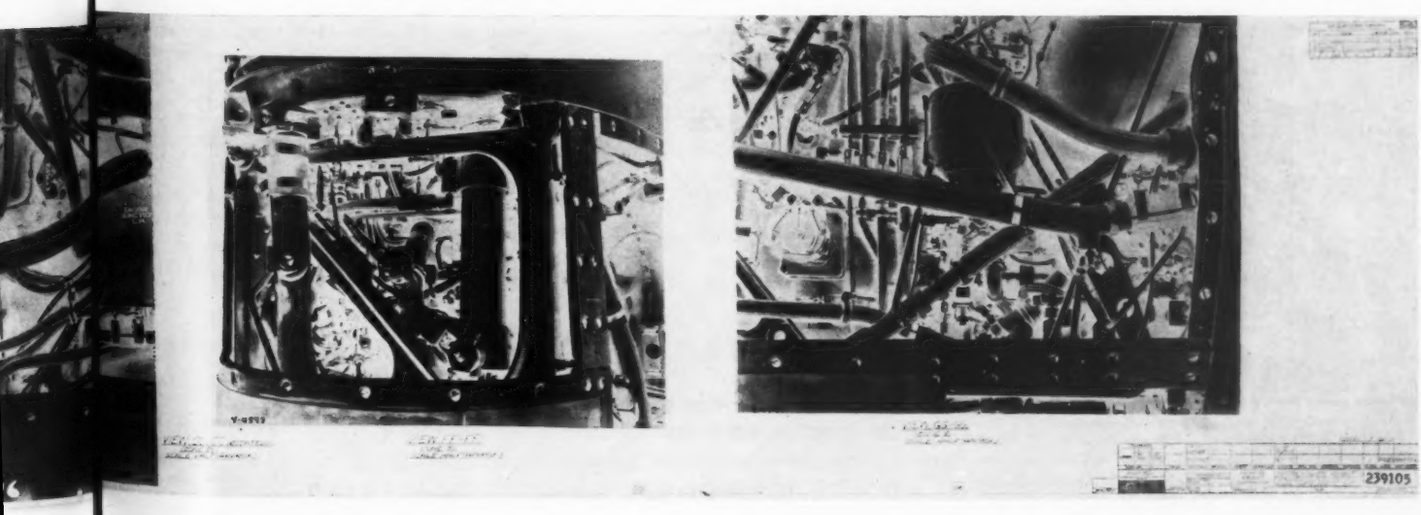
Photostats of photoprints, graphs, charts and service data are also used in Lockheed Service Manuals, thus producing an inexpensive, quick and detailed description of service problems and their solutions.

Comparison of Photo-Tracing and Photostat-Tracing Methods

Advantages	
Photo-Tracing	**Photostat-Tracing**
1. 40 in. maximum width	1. Pencil lettering
2. Cloth stands abuse	2. Low initial cost
3. Unlimited depth of focus	3. Few intermediate processing steps
4. Negative may be used for future tracing production	4. Low tracing production time
	5. Low finished cost

Disadvantages	
1. Ink lettering	1. Standard machine limitations 18 in. width
2. High initial cost	2. Will not stand excessive abuse
3. Numerous intermediate processing steps	3. Limited depth of focus
4. High tracing production time	4. No negative available for future tracing production
5. High finished cost	

Fig. 4—Pictures can be exposed in progression, as shown here, without cutting the sensitized paper after each exposure



Aircraft Hydraulic Control And Power Systems—I

First of a series of articles in which are analyzed the fundamental considerations involved in the design of hydraulic circuits for aircraft. This part deals with the basic circuit and the problems encountered when a number of cylinders are connected to a common pressure line.

BEFORE deciding to use a system for the transmission of power by means of fluid under pressure, rather than by mechanical or electrical arrangements or some other means, the aircraft engineer weighs the relative advantages of each system one against the other. Factors considered are the source of power, the type and size of the energy carrying parts, the distance over which the energy is transmitted, and the devices necessary to convert energy back into power.

Among the important advantages of the hydraulic form of power transmission are light weight, controllability, and low inertia of the moving parts. All of these obviously are especially desirable in aircraft designs. But the weight advantage of hydraulic systems is confined to those using high unit pressures, for with low pressure systems the weight-power ratio of the parts available or practical becomes increasingly large when compared with that of competing systems of power transmission.

The high degree of controllability inherent in hydraulic systems makes them the logical answer to many airplane problems involving the design of power flight controls, power gun turrets and power brakes.

Moving parts having low inertia are an advantage when bringing some mechanism, as a retractable landing gear, to a stop in an exact position. A lightweight part moving at low speed, such as a piston in a cylinder, can usually be stopped by some simple mechanical means.

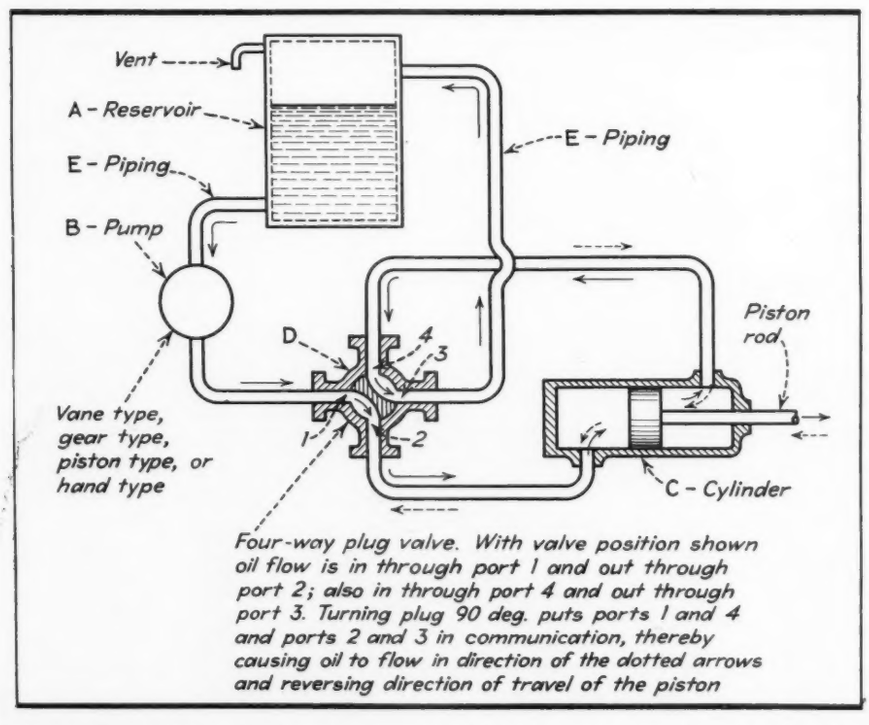

Vent
A - Reservoir
E - Piping
B - Pump
E - Piping
D
4
3
1
2
Piston rod
C - Cylinder
Vane type, gear type, piston type, or hand type
Four-way plug valve. With valve position shown oil flow is in through port 1 and out through port 2; also in through port 4 and out through port 3. Turning plug 90 deg. puts ports 1 and 4 and ports 2 and 3 in communication, thereby causing oil to flow in direction of the dotted arrows and reversing direction of travel of the piston

Fig. 1—Basic airplane hydraulic system to which other units can be added for the purpose of providing multiple sources of power, additional operating cylinders, and for making operations automatic

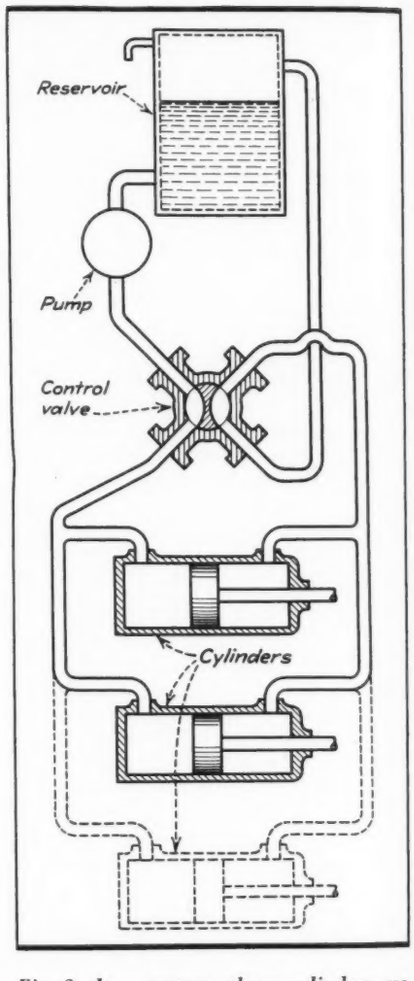


Fig. 2—In a system where cylinders are connected in parallel the sequence of operations is determined by the unit pressures needed to move the load on each individual piston

Pumps for generating hydraulic power in aircraft are commonly mounted on the main engines. But auxiliary engines or electric motors are also used to drive pumps.

In the basic airplane hydraulic system shown in Fig. 1, there are in addition to the pump *B*, the pipe lines *E* and the operating cylinder *C*, a reservoir *A* and a directional control or four-way valve *D*. The reservoir is necessary in most systems to serve as a

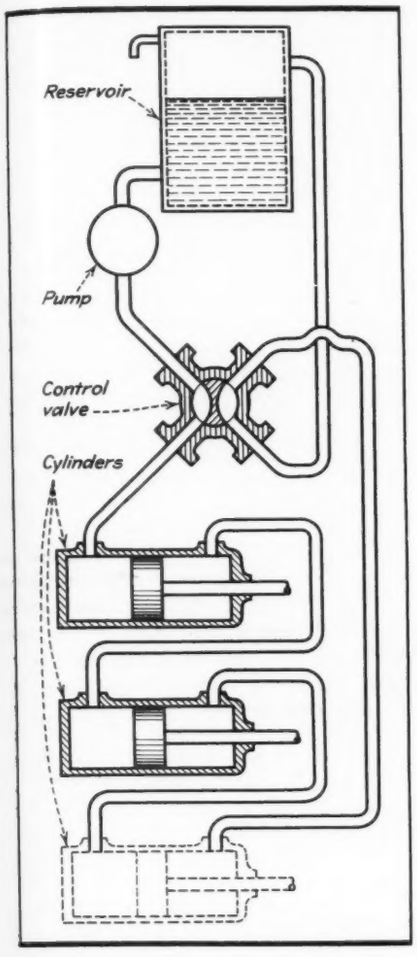


Fig. 3—In a system where cylinders are connected in series, all pistons move simultaneously, since the discharge from the first cylinder is forced into the second cylinder, and that from the second is forced into the third, this continues until the fluid in the exhaust side of the last cylinder can return to the reservoir

vented chamber in which to accommodate the change in volume of the fluid resulting from changes in temperature. The reservoir also takes care of the changes in volume in parts of the system which occur when the operating cylinders are moved because of the difference in the effective areas of the piston end and the piston rod end of the cylinders. The reservoir supply also makes up losses caused by leakage and evaporation. Unless a reversible pump is used, a directional control or four-way valve is required in any system that must operate in two directions.

The reservoir, piping from reservoir to pump, the pump, piping from pump to control valve, and the piping from control valve to reservoir, taken all together are commonly called the power system. The piping from control valve to the operating cylinder, the operating cylinder, and the piping from operating cylinder to control valve taken together are known by the name of the unit which they operate, as the landing gear retracting system, or the flap system.

From this basic system any hydraulic system can be derived. Additions can be made for the purpose of providing sources of power, for operating more than one cylinder, and for making operations more automatic or for increasing their reliability.

Airplanes of a few years ago used systems almost identical with that shown in Fig. 1. They consisted of a fluid supply reservoir, a pump usually manually operated, a valve and one, or if a landing gear was to be retracted usually two, operating cylinders. Thus the first addition to the basic system was another cylinder to operate retractable landing gears. The full lines of Fig. 2 show a system having two operating cylinders.

As shown by Figs. 2 and 3 any number of cylinders can be added on one valve circuit either in parallel or in series. Since the unit hydraulic pressure is equal throughout all connected branches of a system in which fluid is free to flow, except for line loss which is small compared to the pressure available, when cylinders are added in parallel the piston that requires the lowest unit pressure to move its load will operate first, and it will continue to move until it reaches the end of its travel or until the unit pressure builds up sufficiently to enable another piston to move its load. This process of increasing pressure continues until the cylinder which requires the greatest unit pressure for operation has moved.

In a system of cylinders in parallel, the motions of the pistons are not synchronized. The sequence of operations is determined by the unit pressures needed to move the load on each individual piston. This explains why, in landing gears that are retracted hydraulically, one wheel often retracts completely before the other starts. The cylinders being of the same diameter, the wheel which retracted first either had less airload, less bearing friction, a slightly lower weight, or for some reason required a lower unit pressure to operate.

When cylinders are connected in series as shown in Fig. 3, an entirely different condition results. Fluid is then trapped between the cylinders, only the fluid in the exhaust side of the last cylinder in the series can return to the reservoir. When the valve is operated this trapped oil will be forced from the first cylinder into the second, and from the second into the third. Note that the fluid displacement on opposite sides of each piston differs by an amount equal to the volume of the piston rod. Therefore even if all three cylinders are of the same area there is a small differ-

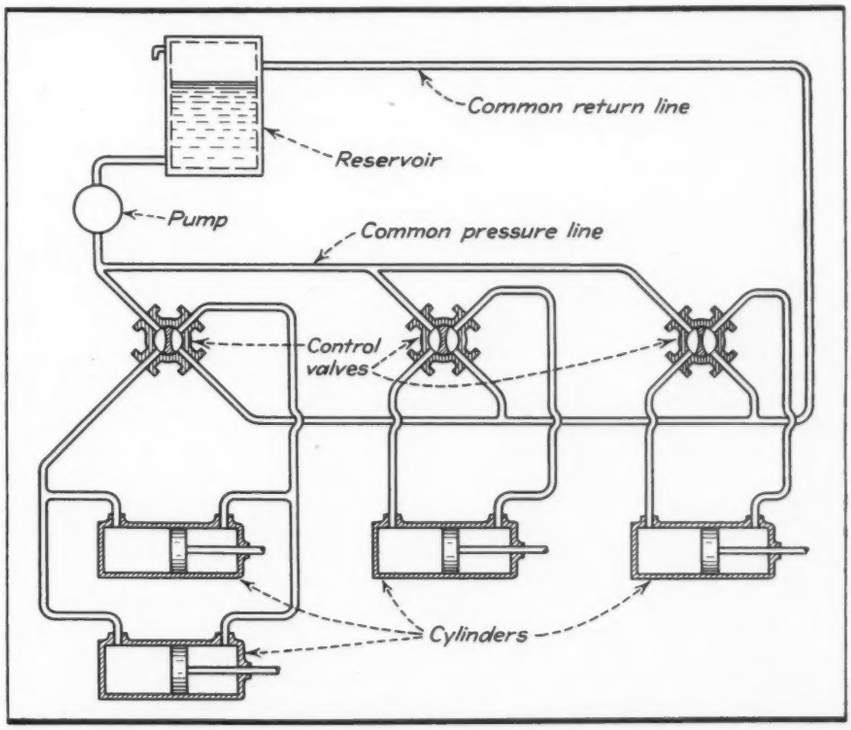


Fig. 4—More than one valve is required on a power circuit when it is desirable to operate and to control more than one service from a common pressure line

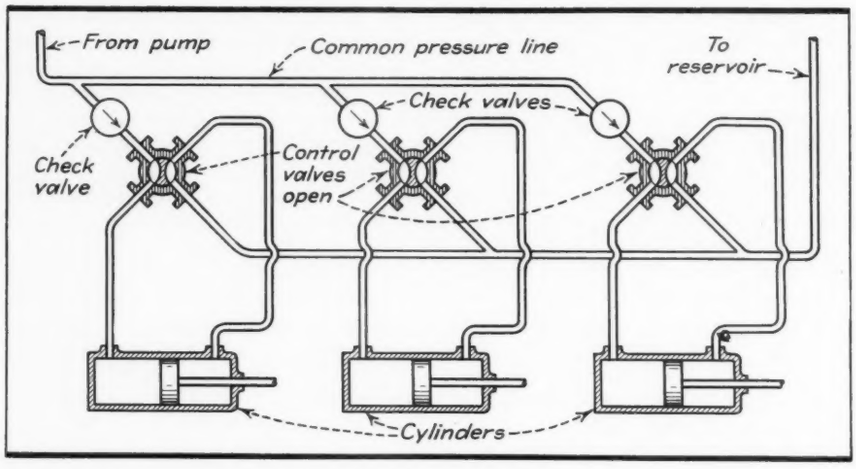


Fig. 5—Check valves are needed in multi-cylinder systems to prevent the fluid from flowing back out of a highly loaded cylinder into a lightly loaded cylinder

ence in their rates of movement. Unfortunately the trapping of fluid between one cylinder and the next introduces serious complications into the design of the system. A slight leakage of the fluid trapped between the cylinders will result in the pistons getting out of synchronism, for when the first piston has reached the end of its travel the second piston will not have quite reached the end of its travel because of the reduced quantity of trapped fluid remaining after leakage. A similar problem, but in the reverse order, occurs when the trapped fluid expands as a result of an increase in temperature. These difficulties can be overcome by the use of synchronizing valves arranged to open automatically, when the pistons reach the ends of their travel, in order to permit a flow of fluid into the cylinder to replace leakage.

A further disadvantage of series cylinder arrangements is undesirable weight, as each cylinder must be designed to withstand the unit pressure required to move the sum of the loads on all the cylinders which follow.

The next addition to the basic hydraulic system came when it was found desirable to operate and to control more than one service, as landing gear and wing flap from one source of power. This requires more than one valve on the same power circuit as shown in Fig. 4. Obviously if all the valves except one are closed, the number of valves does not affect the operation of the system connected to the open valve in any way different from that of the hydraulic systems previously described. But if two or more valves are open simultaneously then the system requiring the least unit pressure to operate will operate first, and will continue to operate until it reaches the end of its travel or until the load on it increases

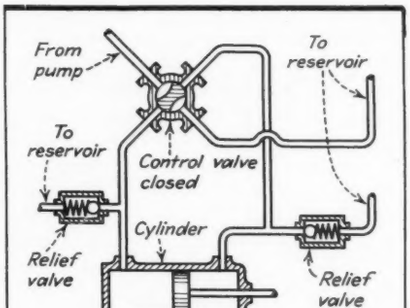


Fig. 6—Pressure relief valves in cylinder lines are used when the control valve is normally closed whenever the low pressure reulting from a temperature decrease is not detrimental

and requires a higher unit pressure than that required to move some other piston.

Two general principles apply to all hydraulic systems:

1. Flow in a hydraulic system always tends to equalize pressures, that is, to build up low pressures and to reduce high pressures.
2. Fluid is incompressible, therefore, the volume in a sub-system remains the same, plus pump input minus flow to reservoir.

Application of these principles to a multi-cylinder system explains why after a highly loaded piston has reached the end of its travel with its control valve still open, if the control valve leading to a lightly loaded cylinder is operated, that the fluid will flow back out of the highly loaded system into the lightly loaded cylinder until unit pressures balance or the end of the travel is reached. Often check valves are connected as shown in Fig. 5 to prevent interflow between valves.

Whenever a hydraulic system is to be closed off for a period of time it becomes necessary to add some means, spring loaded expansion chambers or relief valves, to relieve the increase in the fluid volume in a closed system caused by an increase in the temperature of the outside air.

Relief valves are by far the most common means of preventing pressure in closed lines from building up because of an increase in volume caused by rising temperature. Relief valves are used wherever the low pressure resulting from a temperature decrease, following a previous temperature increase which has caused fluid to be relieved from the system, is not detrimental. Where the pressure must be kept up, as in parking airplanes equipped with hydraulic brakes, a spring loaded expansion chamber is required.

In hydraulic circuits where the control valve is normally in the "off" position, it is necessary, as shown in Fig. 6, to add a relief valve in each cylinder line. When the valve is normally in its operating position rather than in the "off" position, it is only necessary to provide a relief valve in the pressure line leading to the valve. This relief valve must be between the control valve and any check valve that would prevent a back flow out of the pressure line. If individual check valves installed for the prevention of interflow between control valves are used in front of each control valve then a separate relief valve is required as shown in Fig. 7 for each directional control valve.

The foregoing describes the development of an airplane hydraulic system from the common pressure line onward. The system described contains only those units common to all sub-systems. Special purpose units are often added such as hydraulic landing gear locks and special flap relief valves.

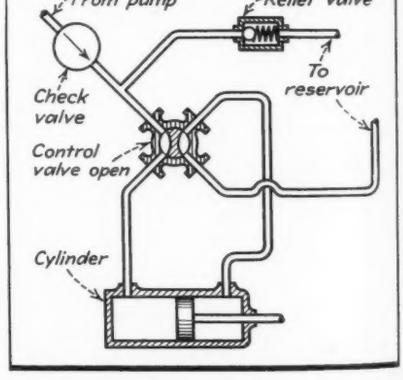


Fig. 7—When the control valve is normally open, relief valves should be between the check valve in the pressure line and the control valve

Formulas for Calculating Press Fits in Aluminum Rings

H. N. HILL
Aluminum Company of America

Formulas for radial and maximum stresses produced by a steel bushing pressed into a round hole in an aluminum fitting are developed for idealized conditions. Formulas and equations which are here derived are applicable within the elastic range of aluminum.

WHEN a steel bushing is pressed into a hole in an aluminum fitting, stresses are set up whose magnitudes depend on the interference or difference in diameter of bushing and hole, the size and shape of the two pieces, and certain physical and mechanical properties of the two materials. For the idealized case in which a cylindrical steel bushing of uniform wall thickness is pressed into a central circular hole in an aluminum ring of uniform depth, equal to the length of the bushing, equations for the stresses produced can be readily derived, provided these stresses do not exceed the range of elastic action. In deriving these equations, it has been assumed that the temperature remains constant.

The following nomenclature is used:

a = inside dia. of bushing, in.
b_s = outside dia. of bushing, in.
b_A = inside dia. of ring, in.
b = average of outside dia. of bushing and inside dia. of ring, in. $\left(b = \frac{b_s + b_A}{2}\right)$
D = interference, in. $(D = b_s - b_A)$
c = outside dia. of ring, in.
p = radial pressure between bushing and ring, lb. per sq.in.
E_s = Young's modulus for steel
E_A = Young's modulus for aluminum
μ_s = Poisson's ratio for steel
μ_A = Poisson's ratio for aluminum
S_r = radial stress, lb. per sq.in.
S_t = tangential stress, lb. per sq.in.
τ = shear stress, lb. per sq.in.

$$\left(\tau = \frac{S_t - S_r}{2}\right)$$

Radial Pressure

The external radial pressure on the bushing must be the same as the internal radial pressure on the ring. The sum of the decrease in diameter of the bushing and the increase in diameter of the hole in the ring must equal the initial interference. The changes in diameter of bushing and ring, as expressed by S. Timoshenko, "Strength of Materials, Part II, 1930, p. 533, and Raymond J. Roark, "Formulas for Stress and Strain," 1938, p. 232, are:

$$\Delta b_s = \frac{pb}{E_s}\left(\frac{a^2 + b^2}{b^2 - a^2} - \mu_s\right)$$

and $$\Delta b_A = \frac{pb}{E_A}\left(\frac{b^2 + c^2}{c^2 - b^2} + \mu_A\right)$$

Since $D = \Delta b_s + \Delta b_A$

$$D = pb\left[\frac{1}{E_s}\left(\frac{a^2 + b^2}{b^2 - a^2} - \mu_s\right) + \frac{1}{E_A}\left(\frac{b^2 + c^2}{c^2 - b^2} + \mu_A\right)\right]$$

Therefore $$p = D\Big/\left\{b\left[\frac{1}{E_s}\left(\frac{a^2 + b^2}{b^2 - a^2} - \mu_s\right) + \frac{1}{E_A}\left(\frac{b^2 + c^2}{c^2 - b^2} + \mu_A\right)\right]\right\} \quad (1)$$

This expression can be expanded and simplified for this case by making the following substitutions:

$E_s = 29{,}000{,}000$
$\mu_s = 1/4$
$E_A = 10{,}500{,}000$
$\mu_A = 1/3$

The resulting equation is

$$p = 10^8\, D\,(b^2 - a^2)(c^2 - b^2)/\{b[b^2(15.3\,c^2 + 3.76\,b^2 - 10.7\,a^2) - 8.39\,a^2\,c^2]\}$$

Having this expression for radial pressure between bushing and ring, stresses in the two pieces can be obtained by substitution in the usual equations for stresses in thick cylinders, as given in the references cited above.

Stresses in the Ring

Maximum stresses in the ring will exist at the inner surface, where

$$S_r = -\,p;\ S_t = p\,\frac{c^2 + b^2}{c^2 - b^2};\ \tau_{max.} = p\,\frac{c^2}{c^2 - b^2} \quad (2)$$

Stresses in the Bushing

Maximum tangential and shear stresses will occur at the inner surface of the bushing. The greatest radial stress will, of course, exist at the outer surface. Values for stresses at the inner surface of the bushing may be obtained from the equations

$$S_r = o;\ S_t = -\,p\,\frac{2b^2}{b^2 - a^2};\ \tau_{max.} = p\,\frac{b^2}{b^2 - a^2} \quad (3)$$

Equations (1), (2), and (3) are applicable only within the elastic range, i. e., for stresses at which there is no yielding of the material. According to the "maximum shear stress theory," yielding will occur when $\tau_{max.}$ equals one-half the tensile or compressive stress which will produce yielding under uniaxial stress. The more nearly correct "shear strain energy theory" indicates that yielding will occur when $\tau_{max.}$ is slightly more than one-half the uniaxial stress producing yielding. The maximum difference in $\tau_{max.}$ values to produce yielding, according to the two theories, is about 15 percent.

Considering the exactness with which stresses are generally known, the "maximum shear stress theory" is generally considered satisfactory for practical applications of this kind. This theory is simple to apply.

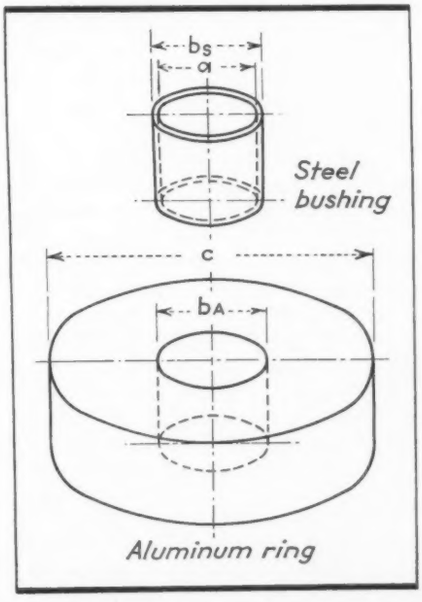


Fig. 1—Formulas for stresses apply to the idealized shapes shown here. The two parts have the same length.

Models and Analogues For Solving Design Problems

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This discussion examines the field for the dimensional analysis method in engineering calculations and in experimental work with mechanical models, and also describes the design of electrical analogues and their use in solving some types of mechanical problems.

MATHEMATICAL solutions of many engineering problems are frequently so complicated that direct answers cannot be obtained. If experimental methods are to be applied, the scope of the results can frequently be increased through the use of dimensional analysis. There is, in addition to the dimensional analysis approach, the important fields of analogies and models which may be drawn upon for the solution of many problems. The fact that many different physical phenomena can be represented by similar or equivalent equations may permit the results found in one field of science to be applied or used in some other field. In some fields of science experimental work can be carried out conveniently and economically, whereas in others experimental work may be difficult or impossible.

The general scope and the method of using dimensional analysis are frequently misunderstood. Dimensional analysis is not and was never intended to be a substitute for scientific analysis. Furthermore, there exists the idea that if one writes down all the things he can think of as affecting the problem, he can solve the problem by the use of the π theorem. Bridgeman's book on "Dimensional Analysis" makes some pertinent comments concerning these notions. He says "The man applying dimensional analysis is not to ask himself 'On what quantities does the result depend?' for this question gets nowhere, and is not pertinent. Instead we are to imagine ourselves as writing out the equations of motion at least in sufficient detail to be able to enumerate the elements which enter them." Further he says "It appears, therefore, that dimensional analysis is essentially of the nature of an analysis of an analysis."

Where the nature of the answer is known, dimensional analysis can often be used effectively. For a complicated problem this method of analysis may not be of much help until experimental analysis gives some clues as to the nature of the problem.

There is another method of applying the dimensionless principle which has not been used extensively and which can be effectively used for the solution of problems that can be expressed in the form of a differential equation. ("An Investigation of Experimental Methods of Determining Sucker Rod Loads," *Trans., A.I.M.E.*, Vol. 118, 1936). This method is to reduce the form of the variables in a differential equation to a dimensionless form, from which the dimensionless quantities can be found. In Fig. 1 is shown a vibrating system with damping which is assumed to be proportional to the velocity. The

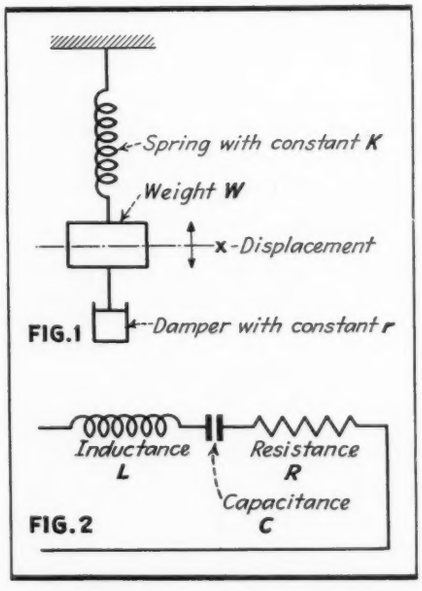


Fig. 1—Vibrating system with damping which is assumed to be proportional to the velocity. Fig. 2—Schematic for electrical circuit for determining effects produced in a vibrating mechanical system

motion of this system can be represented by a differential equation in which

x = displacement from static position, in.
t = time, sec.
W = weight of body on spring, lb.
r = damping constant, lb. per unit velocity
k = spring constant, lb. per in.
g = 386 in. per sec. per sec.

$$\frac{W}{g}\frac{d^2x}{dt^2} + r\frac{dx}{dt} + kx = 0 \qquad (1)$$

If a new set of variables which are dimensionless and denoted by subscripts are selected as follows:

$$x = x_1 l$$

$$tw = t_1$$

then

$$\frac{dx}{dt} = lw\frac{dx_1}{dt_1}$$

$$\frac{d^2x}{dt^2} = lw^2\frac{d^2x_1}{dt_1^2}$$

Substituting these values in Equation (1)

$$\frac{W}{g}lw^2\frac{d^2x_1}{dt_1^2} + rlw\frac{dx_1}{dt_1} + klx_1 = 0$$

or

$$\frac{d^2x_1}{dt_1^2} + \left[\frac{rg}{Ww}\right]\frac{dx_1}{dt_1} + \left[\frac{kg}{Ww^2}\right]x_1 = 0 \qquad (2)$$

Since x_1 and t_1 are dimensionless it follows that d^2x_1/dt_1^2 and dx_1/dt_1 are dimensionless. The terms in brackets must also be dimensionless and are the dimensionless ratios which govern the system. They can be called dimensionless numbers and given a name if desired. These dimensionless ratios can be expressed in two other forms. These forms can be determined by dividing by the coefficient of the x_1 or the velocity term. In such a case equivalent terms will be obtained. These dimensionless ratios could be obtained by applying the π theorem directly.

If the actual machine being studied is too large to build for experimental investigations, it may be desirable to build a model. Since the differential equation as given in Equation (1) will apply to both the model and machine, it follows that the dimensionless Equation (2) will also be the same. To have the two systems behave similarly, it is only necessary to have the dimensionless constants the same. If the symbols as given apply to the actual machine and the same symbols with the subscipt m apply to the model, then by letting C_1

and C_2 represent the two dimensionless constants

$$C_1 = \frac{rg}{Ww} = \frac{r_m g_m}{W_m w_m} \qquad (3)$$

$$C_2 = \frac{kg}{Ww^2} = \frac{k_m g_m}{W_m w^2_m} \qquad (4)$$

Since there are five factors involved and only two equations to be solved, any three of the values for the model can be arbitrarily set up and the other two calculated. Since g is normally fixed, only two can be selected at will.

The development of the cathode ray oscillograph makes it possible to set up many types of electrical circuits and analyze them experimentally in a very short time. If, then, a mechanical problem can be reduced to an equivalent electrical circuit, it may be possible to obtain a complete solution much easier. Problems similar to that shown in Fig. 1 involving energy interchange and dissipation are very similar to those encountered in electrical circuits.

Where L = inductance, henries
Q = charge
R = resistance, ohms
c = capacitance, farads
t = time

the differential equation for an electrical circuit involving the equivalent of velocity damping and interchange of kinetic and potential energy is

$$L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + (1/c)\,Q = 0 \qquad (5)$$

A comparison of Equations (1) and (5) shows that by letting the following symbols be identical the two differential equations will be identical.

$$\frac{W}{g} \underline{=} L, \qquad R \underline{=} r, \qquad 1/c \underline{=} k, \qquad q \underline{=} x$$

With these identities it is obvious that the equivalent dimensionless constants in the electrical Equation (5) would be equal to those in the mechanical equation and that the following relations can be written if the two systems are to be equivalent

$$C_1 = \frac{rg}{Ww} = \frac{R}{L\nu} \qquad (6)$$

$$C_2 = \frac{kg}{Ww^2} = \frac{1}{cL\nu^2} \qquad (7)$$

In this case ν represents the frequency of the electrical system to distinguish it from the frequency of the mechanical system. As in the case of the mechanical model, the electrical model can be operated at a different frequency from the mechanical system if desired. As an example consider that it is desired to find the proportions of an electrical model to correspond to the system shown in Fig. 1 when

k = 20 lb. per in.
W = 2 lb.
g = 386 in. per sec. per sec.
r = 0.10 lb. per sec. per ft.
$\nu = 30w$

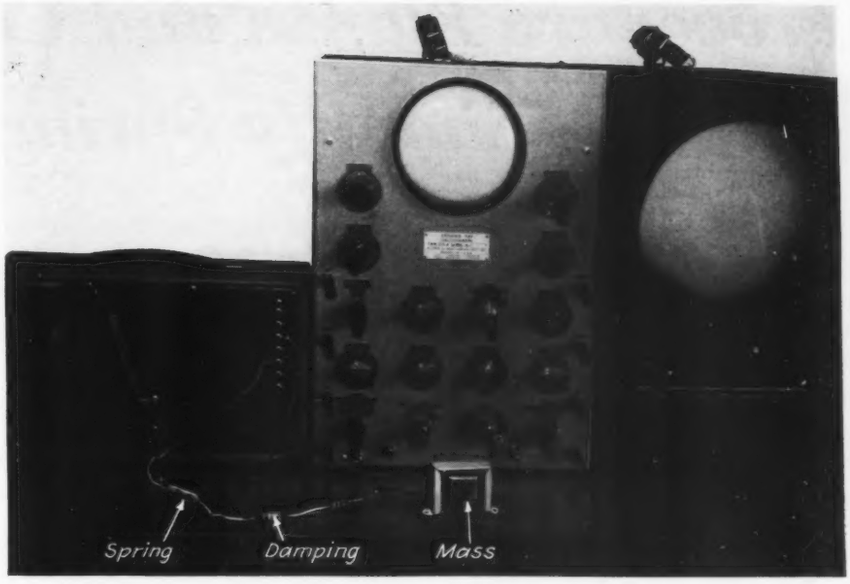


Fig. 3 —Inductance, capacitance and resistance in an electric circuit to represent spring, damping and mass to determine the natural frequency of a mechanical system

Then from Equation (6)

$$C_1 = \frac{0.1 \times 386}{2 \times w} = \frac{R}{L \times 30w}$$

$$R = 580\,L \qquad (8)$$

and from Equation (7)

$$C_2 = \frac{20 \times 386}{2 \times w^2} = \frac{1}{c\,L\,(30w)^2}$$

$$c = \frac{1}{3.47 \times 10^6\,L} \qquad (9)$$

If L is selected, R and C will be determined. For example if a value for L equal to 30 henries is used, from the Equations (8) and (9)

$$R = 580 \times 30 = 17{,}400 \text{ ohms}$$

$$c = \frac{1}{3.47 \times 10^6 \times 30} = 0.0097 \text{ microfarads}$$

If then an electrical circuit be set up as indicated in Fig. 2 and the values of the inductance, capacitance and resistance as calculated be used, the results for the mechanical system shown in Fig. 1 can be determined.

Such models can be used for several purposes. One would be to determine the natural frequency of the system. This could be determined by connecting a beat frequency oscillator to the input, and by varying the frequency, the value corresponding to the natural frequency of the system can be determined. This will be indicated by a large increase in velocity in the mechanical system or current in the electrical circuit. For simple systems analytical methods can be readily used. For complicated systems some method such as this may have decided advantages.

The equipment necessary to determine the natural frequency of such a system is shown in Fig. 3. The oscillator shown has a constant voltage output which corresponds to a constant impressed force being applied to the mass. The amplitude of the motion will be related to the velocity and can be determined by measuring the voltage drop across the resistance. This voltage drop is proportional to the current flowing which in turn is proportional to the velocity of the mass. In the electrical equations dq/dt corresponds to the current i flowing and this in turn is proportional to dx/dt or the velocity in the mechanical system. Since the displacement is given by

$$s = \int v\,dt$$

the equivalent of the mechanical displacement can be found by integrating the current wave electrically. The resultant wave will correspond to the displacement. If the impressed voltage is sinusoidal, the current will be sinusoidal. The displacement will then likewise be sinusoidal so that the amplitude of the current, or velocity in the mechanical system, will be an index of the displacement.

When resonance occurs the amplitude of the displacement is a maximum. The corresponding natural frequency can be found by watching the amplitude of the current as indicated by the voltage drop across the resistance in the circuit.

Another method of determining the critical frequency of a simple system is to charge the condenser and then close the circuit. By measuring voltage or current in a part of the circuit the natural frequency can be found by examination of a frequency curve.

Procedure Blanks and Charts Simplify Spring Design Jobs

CARL THUMIM
General Electric Company

Work-proven "cook-book" method of spring calculation, in which known important factors are automatically included, can successfully be used by an average drafting room employee. The method requires the filling in of forms with the help of special charts. Results of the calculations are then summarized in a specification sheet which gives all the information the manufacturer needs.

BASIS of this spring calculation proceaure is the blank form shown in Fig. 1 which can be filled in with simple calculations and quick references to the tables. Generally neglected factors which permit most efficient utilization of material have been taken into consideration in the tables. The method will apply directly to round wire, carbon steel, compression and tension springs having commercial tolerances for economical manufacture. For other cross-sections and materials, the general method can be followed but special tables should be made up for convenience. In some cases as shown later, the spring steel tables may be used with conversion factors.

The constants of a spring will be denoted by the following:

d = diameter of wire
D = pitch diameter of coil
OD = outside diameter of coil = $d + D$
N = number of active turns
H = free height
h = solid height
f' = deflection per active turn to give S
G = torsional modulus of elasticity
S = basic fibre stress
P' = load to give S stress
f = deflection per active turn to give P
P = load to give fibre stress modified by the Wahl factor
K = Wahl factor
$c = D/d$

No more than passing mention need be given to the standard formulas

$$P' = \frac{d^2S}{8D}$$

and

$$f' = \frac{D^2S}{Gd}$$

upon which the spring table is based, except to note that the ratio P'/f' is a constant.

Stress Concentration

Wahl (A.S.M.E. *Transactions*, 1928) has shown that especially in heavy close-coiled springs, the fibre stress on the inside of the coils is much greater

Fig. 1—Design Procedure for Standard Compression and Tension Springs

DESIRED SPECIFICATIONS

1. W = Desired force at maximum deflection _____ lb.
*2. $W_{max.} = 1.1W$ (plus commercial tolerance) _____ lb.
*3. $W_{min.} = 0.9W$ (minus commercial tolerance) _____ lb.
4. w = Desired force at minimum deflection _____ lb.
5. t = Desired travel between W and w _____ in.
6. T = Deflection from zero to $W = (W \times t)/(W - w)$ _____ in.
7. R = Stress range $= (W - w)/W$ _____
8. A = Number of operations for life of device _____
9. C = Correction factor from Table II _____
10. $P_1 = W/C$ _____ lb.

SELECTED SPECIFICATIONS (from Table I)

*11. P = Chart load (must be greater than P_1) _____ lb.
12. f = Chart deflection per turn _____ in.
13. OD = Outside diameter of coil _____ in
14. d = Diameter of wire _____ in.
15. f_1 = Deflection per turn at W load $= f \times W/P$ _____ in.
16. N = No. of turns $= T/f_1$ (3 significant places) _____
17. J = Gradient $= P/(N \times f)$ (3 significant places) _____ lb./in.

COMPRESSION SPRINGS

*18. h = Max. solid height $= d\ (N + e)$ (See Table III) _____ in.
*19. L = Min. operating length − may vary from $(h + 0.125T)$ to $(h + 0.4T)$. _____ in.
20. H = Free length $= L + T$ (take nearest $\frac{1}{16}$ in.) _____ in.
21. H_w = Initial operating length $= H - w/J$ _____ in.
22. H_W = Final operating length $= H - W/J$ _____ in.
23. Check: $H_w - H_W = t$

TENSION SPRINGS

24. h = Length of spring body $= d\ (N_1 + 1)$ (Where N_1 is nearest even or ½ turn above N) _____ in.
25. a = Left-hand loop _____ in.
26. b = Right-hand loop _____ in.
27. $H = h + a + b$ (take nearest $\frac{1}{16}$ in. above) _____ in.
28. $H_w = H + w/J$ _____ in.
29. $H_W = H + W/J$ _____ in.
30. Check: $H_w - H_W = t$

MANUFACTURING TOLERANCES

31. B = Tolerance on OD (from Table IV) _____ in.
32. $OD_{max.} = OD + B$ _____ in.
33. $ID_{min.} = OD - 2d - B$ _____ in.
34. $c = (OD - d)/d$ _____
35. Coils per inch $= N/H$ (compression springs) _____
or $= N/h$ (tension springs) _____
36. m (Selected from Table IV using nearest values) _____ in.
37. M = Free length tolerance $= m \times H$ (compression springs) _____ in.
or $= m \times h$ (tension springs) _____ in.
38. $H_{max.}$ = Max. free length $= H + M$ _____ in.
39. $H_{min.}$ = Min. free length $= H - M$ _____ in.

* Refer to these numbers in text for more detailed explanation

TABLE I—TENSION AND CO

Includes Wa

Spring Steel Wire – See Tab

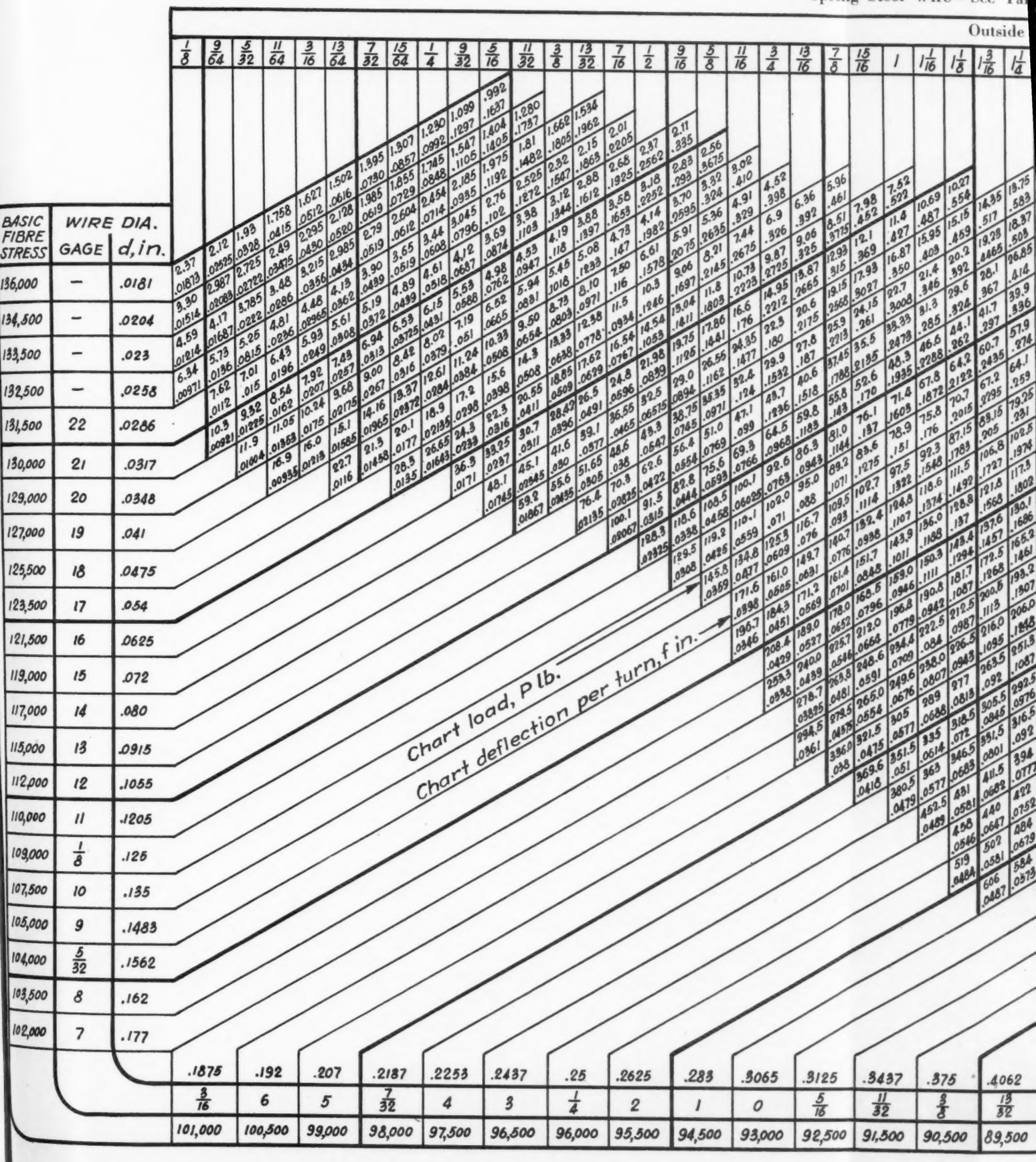


TABLE I—TENSION AND COMPRESSION SPRING CHART

Includes Wahl Factor

Spring Steel Wire – See Table V for Other Materials

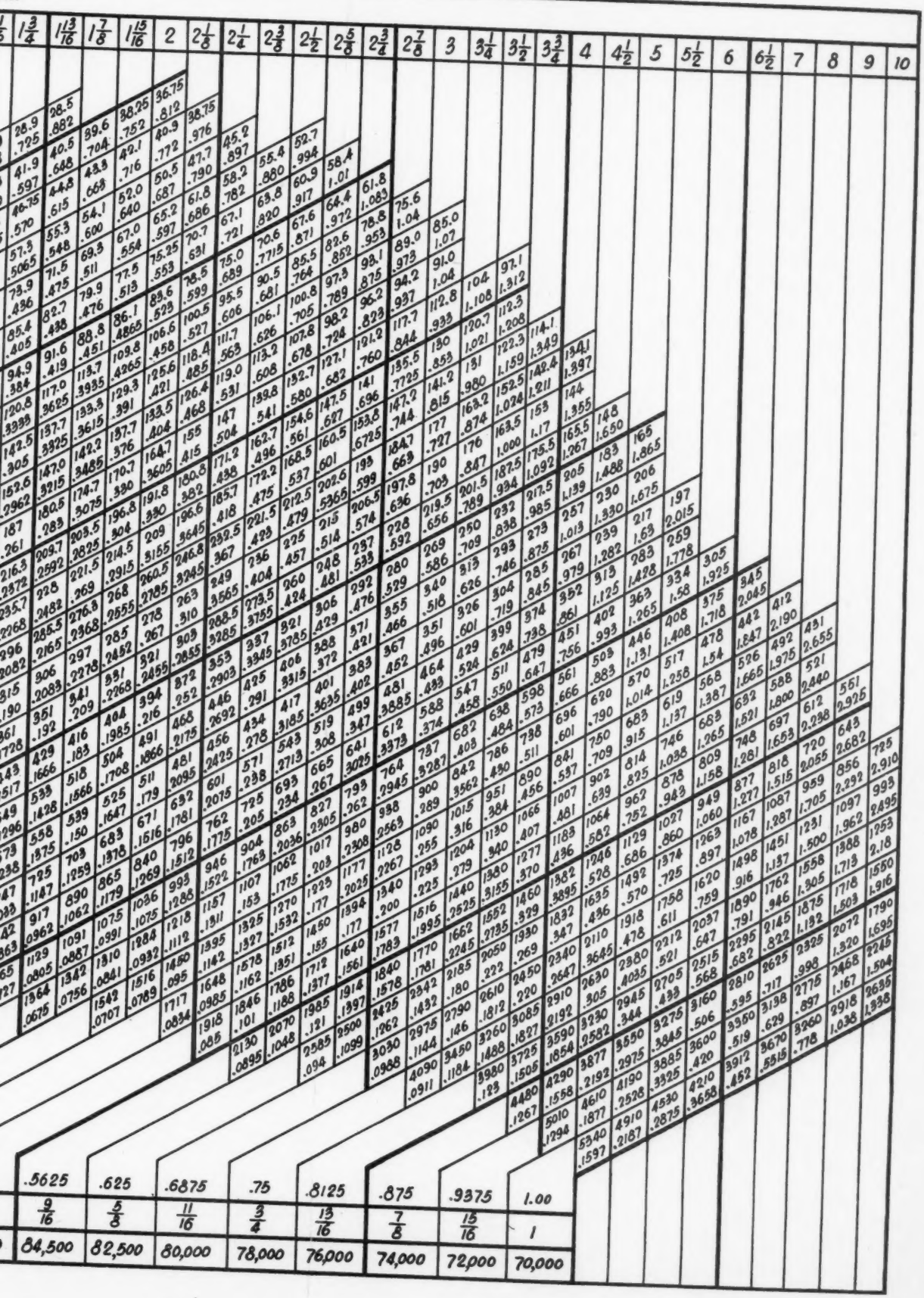
Outside Diameter of Springs, OD, in.

9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/16	1 1/8	1 3/16	1 1/4	1 5/16	1 3/8	1 7/16	1 1/2	1 9/16	1 5/8	1 11/16	1 3/4	1 13/16	1 7/8
2.11																					
.335																					
2.83	2.56																				
.293	.3675																				
3.70	3.32	3.02																			
.2595	.324	.410																			
5.91	5.36	4.91	4.52																		
.2075	.2635	.329	.398																		
9.06	8.21	7.44	6.9	6.36	5.96																
.1697	.2145	.2675	.326	.392	.461																
13.04	11.8	10.73	9.87	9.06	8.51	7.98	7.52														
.1411	.1803	.2223	.2725	.325	.3775	.452	.522														
19.75	17.86	16.6	14.95	13.87	12.93	12.1	11.4	10.69	10.27												
.1125	.1441	.176	.2212	.2665	.315	.369	.427	.487	.554												
29.0	26.55	24.35	22.3	20.6	19.15	17.93	16.87	15.95	15.15	14.35	13.75	13.12									
.0894	.1162	.1477	.180	.2175	.2568	.3027	.350	.409	.459	.517	.583	.652									
38.75	35.35	32.4	29.9	27.8	25.9	24.15	22.7	21.4	20.2	19.23	18.37	17.53	16.77	16.1							
.0745	.0971	.124	.1532	.187	.2213	.261	.3008	.346	.392	.4465	.503	.561	.621	.687							
56.4	51.0	47.1	43.7	40.6	37.45	35.5	33.33	31.3	29.6	28.1	26.85	25.55	24.45	23.55	22.58	21.7	20.95				
.0554	.0769	.099	.1236	.1518	.1788	.2135	.2478	.285	.324	.367	.414	.462	.515	.569	.653	.686	.747				
82.8	75.6	69.3	64.5	59.8	55.8	52.6	48.3	46.6	44.1	41.7	39.9	37.9	36.3	34.8	33.42	32.17	31.0	29.9	28.9	28.5	
.444	.0593	.0766	.0968	.1183	.143	.170	.1935	.2288	.262	.297	.336	.375	.417	.465	.509	.567	.611	.668	.725	.882	
118.6	108.5	100.1	92.6	86.9	81.0	76.1	71.4	67.8	64.2	60.7	57.9	55.2	53.0	50.7	48.6	46.65	44.95	43.3	41.9	40.5	39.6
.338	.0458	.06025	.0763	.0943	.1144	.137	.1603	.1872	.2122	.2435	.274	.309	.345	.3815	.421	.464	.506	.550	.597	.648	.704
179.5	164.5	151.7	140.7	131.4	122.8	115.4	107.8	101.7	95.3	89.6	85.7	83.9	79.8	75.9	53.75	51.6	49.75	47.8	46.75	44.8	43.9
.2238	.0425	.0559	.0698	.0848	.1071	.1275	.1492	.1748	.1935	.2216	.2495	.2815	.3125	.3465	.399	.438	.479	.5225	.570	.668	.668
268.5	245.8	227.6	208.4	189.0	178.0	168.5	159.0	150.3	143.4	137.6	130.1	124.7	119.3	114.6	108.6	105.7	101.7	97.8	94.9	91.6	88.8
.1492	.0359	.0398	.0429	.0527	.0652	.0796	.0946	.1111	.1294	.1457	.1686	.1922	.2155	.2405	.2705	.2925	.3225	.3525	.384	.419	.451
		196.7	253.3	240.0	225.7	212.0	199.0	190.8	181.7	172.5	165.2	158.3	152.3	146.3	141.2	135.2	130.2	126.2	120.8	117.0	113.7
		.0346	.0398	.0439	.0546	.0664	.0779	.0942	.1087	.1268	.1461	.165	.1863	.2092	.2335	.2555	.2813	.3075	.3393	.3625	.3935
			208.4	278.7	263.8	248.6	234.4	222.5	212.5	200.5	193.2	185.3	176.7	171.3	164.5	158.0	152.2	149.0	142.5	137.7	133.3
			.0429	.03825	.0481	.0591	.0709	.084	.0987	.1113	.1307	.149	.1663	.1887	.2095	.2318	.2555	.2835	.305	.3325	.3615
			253.3	294.5	279.5	265.0	249.6	238.0	226.5	216.0	206.0	197.0	189.5	187.0	175.3	169.2	163.4	159.5	152.6	147.0	142.2
			.0338	.0361	.0419	.0554	.0676	.0807	.0943	.1095	.1248	.1427	.161	.1804	.208	.2234	.2475	.2708	.2962	.3215	.3485
				321.5	336.0	321.5	305	289	277	263.5	251.3	241.5	232	223	215.4	208	199.5	193	187	180.5	174.7
				.0475	.038	.0475	.0577	.0688	.0813	.092	.1087	.1238	.1398	.1587	.177	.197	.217	.237	.261	.283	.3075
				351.5	369.6	351.5	335	318.5	305.5	292.5	279.5	270	258	248	240	231	224	216.3	209.7	203.5	
				.051	.0418	.051	.0614	.072	.0845	.0976	.1116	.1272	.1417	.159	.1785	.1962	.215	.2372	.2592	.2825	
				380.5	452.5	363	346.5	331.5	316.5	305.5	292	280	268.3	261	252.5	243.5	235.7	228	221.5		
				.0479	.0489	.0577	.0683	.0801	.092	.1063	.1197	.1357	.1508	.1692	.1878	.207	.2268	.2482	.269		
						431	458	411.5	394	379	364.3	351	339	328.5	317.5	306	296	285.5	276.8		
						.0581	.0546	.0682	.0777	.0907	.104	.118	.1324	.1482	.165	.2083	.1822	.2165	.2278		
						440	502	472	484	466	448	431	415	348	336	325	315	297	351	341	
						.0647	.0581	.0752	.0679	.0785	.0896	.1018	.1147	.1402	.1552	.1728	.190	.2268	.192	.209	
						452.5	519	484	562	542	523	504	487	397	385	374	361	325	429	416	
						.0489	.0484	.0573	.0668	.0766	.0874	.0983	.111	.1277	.1428	.1584	.1728	.190	.1666	.183	
							606	584	667	644	623	603	471	457	443	533	518				
							.0487	.0573	.0642	.0741	.0829	.0941	.1238	.1378	.1517	.1428	.1566				
								694	700	676	656	631	584	566	549	558	539				
								.0553	.0618	.0704	.0804	.090	.105	.1169	.1296	.1375	.150				
									857	849	820	794	615	590	573	725	703				
									.0567	.0654	.0741	.0833	.0991	.1123	.1238	.1187	.1259				
										1022	995	967	769	747	917	890					
										.0604	.6685	.0768	.0934	.1033	.0962	.1062					
											1183	1165	942	1129	1091						
											.0638	.0727	.0863	.0805	.0887						
													1364	1342							
													.0675	.0756							

.283	.3065	.3125	.3437	.375	.4062	.4375	.4687	.5	.5312	.5625
1	0	5/16	11/32	3/8	13/32	7/16	15/32	1/2	17/32	9/16
,500	93,000	92,500	91,500	90,500	89,500	88,500	87,500	86,500	85,500	84,500

G CHART

in.


1 3/4
1 13/16
1 7/8
1 15/16
2
2 1/8
2 1/4
2 3/8
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2 5/8
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3 1/4
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9
10
.5625
9/16
84,500
.625
5/8
82,500
.6875
11/16
80,000
.75
3/4
78,000
.8125
13/16
76,000
.875
7/8
74,000
.9375
15/16
72,000
1.00
1
70,000

Table II—Life and Stress Range Factor, *C*

(Apply in step 9, Fig. 1)

R for Compression Springs				*A* = Expected Life, Cycles	*R* for Tension Springs			
0.25	0.50	0.75	1.00		0.25	0.50	0.75	1.00
1.00	1.00	1.00	1.00	100	0.75	0.75	0.75	0.75
0.95	0.91	0.86	0.84	1,000	0.71	0.68	0.64	0.63
0.90	0.82	0.77	0.73	5,000	0.68	0.61	0.58	0.55
0.88	0.79	0.73	0.68	10,000	0.66	0.59	0.55	0.51
0.86	0.75	0.69	0.63	20,000	0.64	0.56	0.52	0.47
0.83	0.68	0.59	0.52	100,000	0.62	0.51	0.44	0.39
0.82	0.63	0.52	0.44	500,000	0.61	0.47	0.39	0.33
0.81	0.61	0.51	0.41	1,000,000	0.61	0.46	0.38	0.31
0.80	0.60	0.50	0.40	10,000,000	0.60	0.45	0.38	0.30

Above values for all spring steels and for beryllium copper. For use with phosphor bronze and Monel metal multiply by 0.5

Table III—Compression Spring End Types

(Apply in step 18, Fig. 1)

Delineation of spring			
End designation	Ends plain ground	Ends squared and ground	Ends squared
e	1	1.5	2

than the stress indicated in the above formulas and that the true load to obtain the basic stress is

$$P = \frac{P'}{K}$$

where $$K = \frac{4c - 1}{4c - 4} + \frac{0.615}{c}$$

Similarly $$f = \frac{f'}{K}$$

Since K is a dimensional constant, it is incorporated in Table I and the need for calculating it is eliminated.

Fibre Stress

The tensile strength of spring wire varies inversely with its diameter. For each wire size in Table I there is a basic fibre stress which permits the best utilization of material. This differs from many spring tables in which the same fibre stress is used for a number of wire sizes.

Life and Stress Range

A large number of tests have demonstrated that to avoid failure, the fibre stress must be lowered as the number of cycles of operation in the expected life increases. This number must include the surges caused by rapid operations or impact. The resulting devaluation factor is partially cancelled by the stress range factor which permits a higher stress as the stress range decreases. Taking w as the initial load on a spring and W as the final load, the stress range $R = (W\text{-}w)/W$. The combination factor for both conditions is listed in Table II.

Table IV—Manufacturer's Tolerances

Outside Diameter
(Apply in step 31, Fig. 1)

OD, in.	*B*, in.
Less than 1/8	0.003
1/8 to 1/4	0.005
1/4 to 1/2	0.008
1/2 to 1	0.015
1 to 2	1/32
2 to 3	1/16
3 and larger	3/32

Free Length
(Apply in step 36, Fig. 1)

Coils per in.	Tolerance *m*, in.		
	c = 4	*c* = 8	*c* = 12
5	0.020	0.030	0.040
10	0.030	0.040	0.050
15	0.040	0.050	0.060
20	0.050	0.060	0.070

Procedure with Blank Form

An example is the best way of illustrating the use of this procedure form in Fig. 1. Suppose the requirement is a steel compression spring delivering 100 lb. final, 50 lb. initial, with a travel of 2 in. for 500,000 operations. The completed form will appear as follows:

1. $W_{spec.}$ = 100 lb.
2. $W_{max.}$ = 1.1 W = 110 lb.
3. $W_{min.}$ = 0.9 W = 90 lb.

These tolerances as well as any of the commercial limits can be narrowed but at a tremendous increase in cost.

4. $w_{spec.}$ = 50 lb.
5. $l_{spec.}$ = 2 in.
6. $T = (100 \times 2)/(100 - 50) = 4$ in.
7. $R = (100 - 50)/100 = 0.50$
8. $A_{spec.}$ = 500,000
9. C = 0.63 (from Table II)
10. $P_1 = 100/0.63 = 159$ lb.

Inspection of Table I indicates that a P somewhat larger than P_1 can be obtained in springs varying in OD from 11/16 minimum to 5 in. maximum. The choice is dictated by the space allowed in the apparatus. Assume that 1½ in. OD is the best for this example. Then, from Table I,

11. P = 164.5 lb.
12. f = 0.2095 in.
13. OD = 1½ in.
14. d = 0.1875 in.
15. $f_1 = 0.2095 \times 100/164.5 =$ 0.1275 in.
16. $N = 4/0.1275 = 31.4$
17. $J = 164.5/(31.4 \times 0.2095) =$ 25 lb./in.

For the compression spring required by specification, where $e = 1.5$ from Table III,

18. $h = 0.1875\ (31.4 + 1.5) = 6.17$ in.

Good design requires that the minimum operating length be greater than the solid height by an amount varying between 0.125 T and 0.4 T, or in this case, by between 0.5 in. and 1.6 in. The minimum operating length could vary between 6.17 + 0.5 = 6.67 in. and 6.17 + 1.6 = 7.77 in. Inspection of the layout indicates that a 7-in. length would be satisfactory. Therefore solving equation $6.17 + 4x = 7$, $x = 0.207$, or the minimum operating length is greater than the solid height by 0.207 T.

19. $L = 6.17 + 0.207 \times 4 =$ 7 in.
20. $H = 7 + 4$ = 11 in.
21. $H_o = 11 - 50/25$ = 9 in.
22. $H_w = 11 - 100/25$ = 7 in.
23. Check 9 − 7 = 2

Manufacturing Tolerances

31. B (from Table IV for a 1½-in. spring) = 1/32 in.
32. $OD_{max.} = 1\frac{1}{2} + 1/32$ = 1 17/32 in.
33. $ID_{min.} = 1\frac{1}{2} - (2 \times 0.1875) - 1/32$ = 1 3/32 in.
34. $c = (1.5 - 0.1875)/0.1875$ = 5.7
35. Coils per inch = 31.4/11 = 2.85
36. m (from Table IV) = 0.020 in.
37. $M = 0.020 \times 11$ = 0.22 in.
38. $H_{max.} = 11 + 0.22$ = 11.22 in.
39. $H_{min.} = 11 - 0.22$ = 10.78 in.

The blank forms for use with this procedure can easily be printed or mimeographed.

Spring Graph

Should it be necessary, the variation in initial load may be obtained from a straight line graph similar to the one

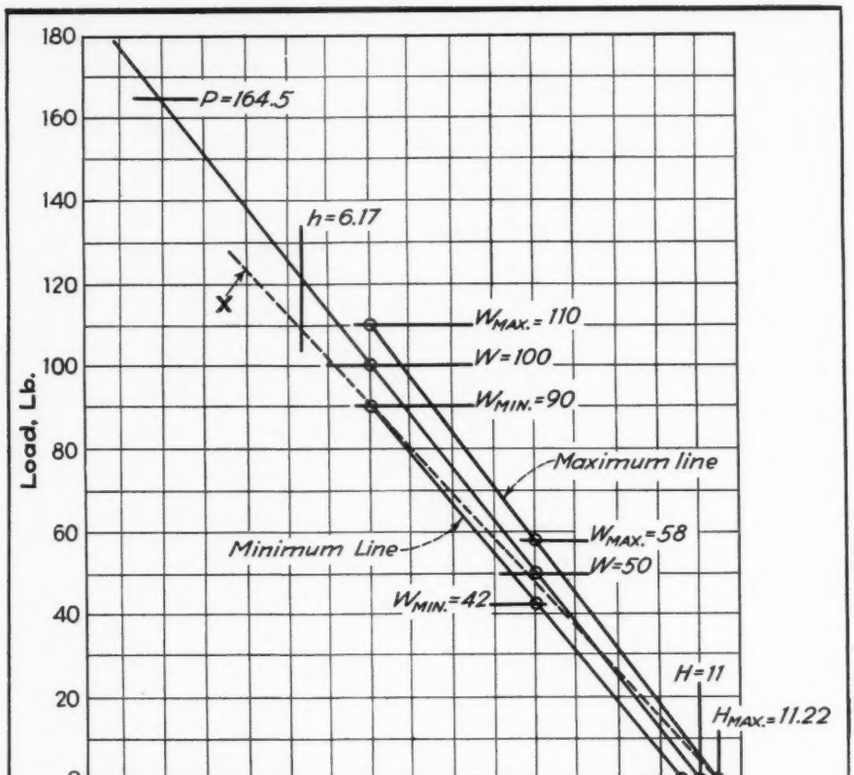


Fig. 2—Spring graph for determining variations in initial load that might be caused by commercial tolerances. Points are plotted from values found in procedure form Fig. 1. Any spring whose graph X falls within maximum and minimum lines meets specifications

REVISIONS
MATERIAL
FINISH
DRAWN BY
INSPECTED
FIRST MADE FOR
SPRING
TEST SPECIFICATION
LENGTH — IN.
ANGLE — DEG.
LOAD INCH POUNDS
MIN.
MAX.
MAX. OUTSIDE DIA. IN.
MIN. INSIDE DIA. IN.
MAX. FREE LG. IN.
MIN. FREE LG. IN.
MAX. SOLID HT. IN.
WIND HAND
REMARKS
OPERATING CONDITION
LENGTH — INCHES
ANGLE — DEGREES
INITIAL
FINAL
NUMBER OF OPERATIONS
SQUARED ENDS AND GROUND
FREE OR TEST LENGTH
TEST LOADS COMPUTED FROM THE FOLLOWING DATA WHICH IS NOT COMPULSORY FOR MANUFACTURE
WIRE DIA. IN.
OUTSIDE DIA. IN.
ACTIVE TURNS
FREE LENGTH IN.
GRADIENT PPI
INITIAL TENSION LB.
SQUARED AND GROUND ENDS TO BE NOT MORE THAN 3 DEG. FROM RIGHT ANGLES TO THE AXIS.
NO PERMANENT SET WILL BE PERMITTED UNDER TEST LOADS.
EACH SPRING MUST BE A TRUE HELIX, CONSTANT PITCH AND FREE FROM SCALE AND BURRS.
THE SPRING WIRE WHEN ETCHED WITH A BOILING SOLUTION OF 30 PER CENT HYDROCHLORIC ACID FOR 15 MIN. SHALL SHOW NO SURFACE IMPERFECTIONS EVEN THOUGH THE WIRE IS TWISTED.
THIRD ANGLE PROJECTION
Name of Company

Fig. 3—When properly filled out, this form gives the spring manufacturer all the information he needs. With few exceptions, data is taken from Fig. 1, procedure form

shown in Fig. 2 in which the spring lengths are plotted against the corresponding loads. Taking the values worked out in this example, obtain the following points (length $H = 11$, load $= 0$) and (length $H_W = 7$, load $W = 100$). Extend this line to reach the solid height h and chart load P. Plot the maximum line (length $H_{max.} = 11.22$; load$=0$); (length $H_W=7$; load $W_{max.} = 110$) and the minimum line (length $H_{min.} = 10.78$; load $= 0$); (length $H_W = 7$; load $W_{min.} = 90$). Drawing a vertical at $H_w = 9$, will check $w = 50$. Where $H_w = 9$ intersects the maximum and minimum lines, in this example at 58 and 42 respectively, will be the possible variation in the initial load of the spring. The graph shows that with commercial tolerances, any spring will fulfill specifications as long as its curve X falls within the area defined by the maximum and minimum lines, H_w, and 0 load.

Table V—Material Conversion Factors

When Using Same Wire Diameter of	Multiply Values in Table I by	
	P	f
Chrome vanadium steel...	1.1	1.1
18–8 stainless steel.....	0.95	1.09
Music wire.....	1.15	1.1

Other Materials

In case of materials other than carbon spring steel, conversion factors shown in Table V may be used. Whenever any of these materials or other materials, such as phosphor bronze, Monel metal or beryllium bronze are used constantly, it pays to make a series of charts so these can be designed directly.

Specification

When the spring design is finished, information must be transmitted to the manufacturer in a form making it possible for him to turn out a satisfactory product. The form and drawing shown in Fig. 3 meets this need. When filed together with Fig. 1 and 2, it gives complete reference data. The information is all obtained from the design procedure sheet (Fig. 1) with the exception of some optional points such as the right or left-hand winding (the latter generally) or finish which may be paint or cadmium plate for steel.

Spring Identification

In cases where it is desirable to find out what a given spring can do, it is necessary to measure only the *OD* of the spring and the d of the wire. Reference to Table I gives the maximum force P which that spring could give. If the average distance between turns is measured or calculated, the ratio of this distance to the f value in the table gives the proportion of P available.

Preferred Numbers, Prefernograph Simplify Product Standardization

JOHN GAILLARD
Mechanical Engineer, American Standards Association

Maximum efficiency in war production demands that luxuries be sacrificed to speed output of necessities. Simplification and standardization of a series of articles can be done scientifically and efficiently with the use of Preferred Numbers and the Prefernograph.

SPEEDY and economical war production calls for concentration on the minimum number of products which will cover all requirements. This concentration naturally leads to establishment of a standard series to be copied by all manufacturers in a given industry. If companies have been making the same product to different designs, the problem of national unification may be solved in one of three ways: the standard series to be adopted may consist solely of units selected from existing series; it may consist of a number of existing units supplemented by others of new design; or an entirely new series may be designed. Whatever the decision, the designer of a standard series has to answer these two questions: (1) Given the total range of requirements specified for the product, how many units should comprise the series? and (2) What shall be the step-up between the units of the series?

Preferred Numbers

The designer may be guided in solving such a problem by the system of Preferred Numbers, approved as an American Standard. This is "a series of numbers selected to be used for standardization purposes in preference to any other numbers." (Copies of the American Standard, Preferred Numbers Z1.1-1936, are available from the American Standards Association, 29 West 39th St., New York, N. Y.) Preferred Numbers apply to linear dimensions, areas, volumes, weights, performance capacities, power ratings and various grades and qualities of materials used in the product.

The system consists mainly of four numerical series, as given in Table I), which divide the range from 10 to 100 into 5, 10, 20 and 40 steps, respectively. In each series, the numbers progress by a stipulated percentage (top of each column, Table I). For all practical purposes, the percentage step-up may be considered as constant throughout the series.

Table I—Basic Preferred Nos. Decimal Series (10 to 100)

These are the basic series for Preferred Numbers. An 80-series, which allows steps-up of about three percent, is available if the 5-, 10-, 20- and 40-series shown here do not suffice.

5-Series (60% Steps)	10-Series (25% Steps)	20-Series (12% Steps)	40-Series (6% Steps)
10	10	10	10
			10.6
		11.2	11.2
			11.8
	12 5	12 5	12.5
			13.2
		14	14
			15
16	16	16	16
			17
		18	18
			19
	20	20	20
			21.2
		22 4	22.4
			23.6
25	25	25	25
			26.5
		28	28
			30
	31 5	31 5	31.5
			33.5
		35 5	35.5
			37.5
40	40	40	40
			42.5
		45	45
			47.5
	50	50	50
			53
		56	56
			60
63	63	63	63
			67
		71	71
			75
	80	80	80
			85
		90	90
			95

When laying out a series of dimensions, capacities, ratings or qualities the designer should first try to confine his choice to the Preferred Numbers of the 5-series. If this gives him too large a step-up between consecutive units, he should try the 10-series, then the 20-series, and finally, the 40-series. If he does not find what he needs even in the 40-series, the American Standard gives him also an 80-series, with a step-up of about 3 percent. Furthermore, by taking every second or third member in one of the five series mentioned so far, the designer can get a step-up of approximately 9, 18, 40, 100, 150 or 300 percent. Hereafter, only the four main series shall be considered.

Origin of Standard Series

Seventy years ago, Colonel Renard of the French Army, being placed in charge of its aeronautical division, found 425 specifications for captive balloon mooring cables. Struck by this excessive variety, Renard analyzed the problem and decided that in covering a range of requirements by a series of units, it is logical to have these units progress in a geometric ratio, or by a constant percentage. For example, a step-up in the rating of a machine from 10 to 12.5 hp. is relatively just as significant as a step-up in a larger unit from 100 to 125 hp. Using this general principal, Renard divided the range between 1 and 10, 10 and 100, and so on, into 5, 10, 20 and 40 equal geometric steps. Therefore, the ratios of the four series are $\sqrt[5]{10}$ which equals 1.5849, $\sqrt[10]{10}$ which equals 1.2589, $\sqrt[20]{10}$ which equals 1.1220 and $\sqrt[40]{10}$ which equals 1.0593, corresponding to approximate step-up percentages of 60, 25, 12 and 6 respectively. The theoretical values thus obtained were rounded. By applying this system to the cable problem, Renard reduced the variety from 425 to 17 sizes and types of cables.

After having remained in relative obscurity for about 40 years, the

"Renard Series," as the French still call them, came to the fore again during and shortly after the first World War. This was attributable to the organization of more than twenty national standardizing bodies which recognized the value of Preferred Numbers as an effective tool for the designer and standardizer. The four series of Table I have practically become a world standard through the recommendation by a committee of the International Standards Association. Today, the value of Preferred Numbers is greater than ever because production must be concentrated on simplified lines of standard units.

Uniform Practice Important

The necessity of a nationally-uniform system of Preferred Numbers has been questioned. Since the principle underlying the standard system can be applied to series with different geometric progressions, should it not be left to each industry to adopt its own series?

The answer is that one of the great advantages of a nationally-uniform system is that it automatically paves the way for the establishment of national standards. In the early stages of an industry, the design of its products is likely to change often, making standardization impossible. However, if from the beginning each individual manufacturer uses Preferred Numbers to determine the basic features of his product, he will have reasonable assurance that when the time is ripe for establishing national standards, general agreement on these points will easily be reached. The products of different manufacturers may then vary in details, but all will be built around the same framework of basic characteristics which are of primary importance in a standardization plan. If, on the contrary, each manufacturer has followed his own set of geometric series, general agreement on a nationally-unified standard for the product will be difficult.

Similarly, Preferred Numbers create prospective harmony between industries having a common interest in the establishment of a specific national standard. For example, if the dimensions, and hence, the cubic contents, of packages are determined by Preferred Numbers, the weights of given materials which fill these packages will also be determined by Preferred Numbers.

These arguments in favor of a unified system of Preferred Numbers apply also to the international aspect of the problem and will carry great weight when the war is over and reconstruction begins.

Use of Graphs

In practice, a standard series must often be established by selecting its units from existing series, for reasons of economy. The designer will then be interested to know how these series compare with Preferred Numbers series. This comparison is facilitated by the use of graphs.

In Fig. 1 is portrayed two series of cubic content ratings (in cu. ft.) of electric refrigerators adopted some years ago by manufacturers A and B. The 10- and 20-series of Preferred Numbers are also shown for approximately the same range, 4 to 20. The graph shows that the ratings A1 to A7 progress with reasonable regularity, except that the last step, A6 to A7, is considerably larger than previous steps. Series B, which covers about the same range with 11 ratings, is more irregular than Series A. In several places, two or three ratings, for example, B2 and B3; B5 and B6; and B9, B10 and B11, are crowded together.

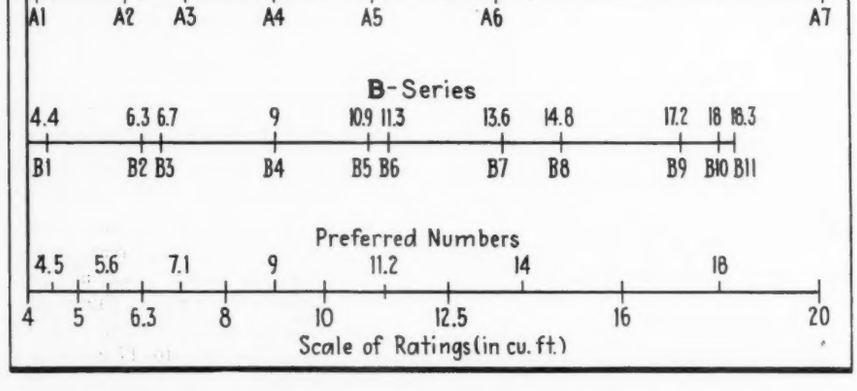


Fig. 1—This graphic presentation of cubic content ratings adopted for electric refrigerators by manufacturers A and B, shows also the Preferred Numbers for the same range

The Prefernograph

While the graph, Fig. 1, indicates at a glance where the ratings of series A and B are located with respect to those of the 10- and 20-series, it does not visualize clearly the step-ups between the successive ratings of a given series. For this purpose, another kind of graph is more useful.

Since the theoretical values of the Preferred Numbers in a given series progress by a constant percentage, their logarithms step up by a constant value. This property of Preferred Numbers forms the basis of what the writer has called the Prefernograph—an abbreviation of "Preferred Numbers graph."

A Prefernograph for the 20-series in the range from 1 to 100 is given in Fig. 2. The numbers are divided into three columns. The first column gives the 5-series. The first two columns together give the 10-series and the first three columns, the 20-series. The scale for the logarithms of the Preferred Numbers is given in the fourth column. The logarithms are those of the theoretical values of the Preferred Numbers, but since the rounded values listed in the first three columns deviate only slightly from the theoretical, the differences are negligible. The horizontal scale carries the serial numbers 1 to 20, to facilitate the plotting of values of a given series. The logarithms of the numbers in the 5-series, plotted vertically above points No. 1 to 10 on the horizontal scale, lie in a straight line as shown by the "5-series" in Fig. 2. The lines representing the 10- and 20-series are also given.

In such a Prefernograph, an existing series of values of dimensions, ratings, etc., can easily be plotted, either by finding the logarithms of these values and plotting them against the scale given in the fourth column, Fig. 2, or by plotting the values themselves directly against the scale of Preferred Numbers given in the third column, Fig. 2. The latter method is somewhat less accurate since the position of the plotted point must be estimated, but often it is accurate enough for the practical purpose and it saves the trouble of looking up logarithms.

Use of the Prefernograph

The refrigerator ratings, series A and B, Fig. 1, have been plotted in the Prefernograph, Fig. 2, series A starting with point No. 4 and series B, with

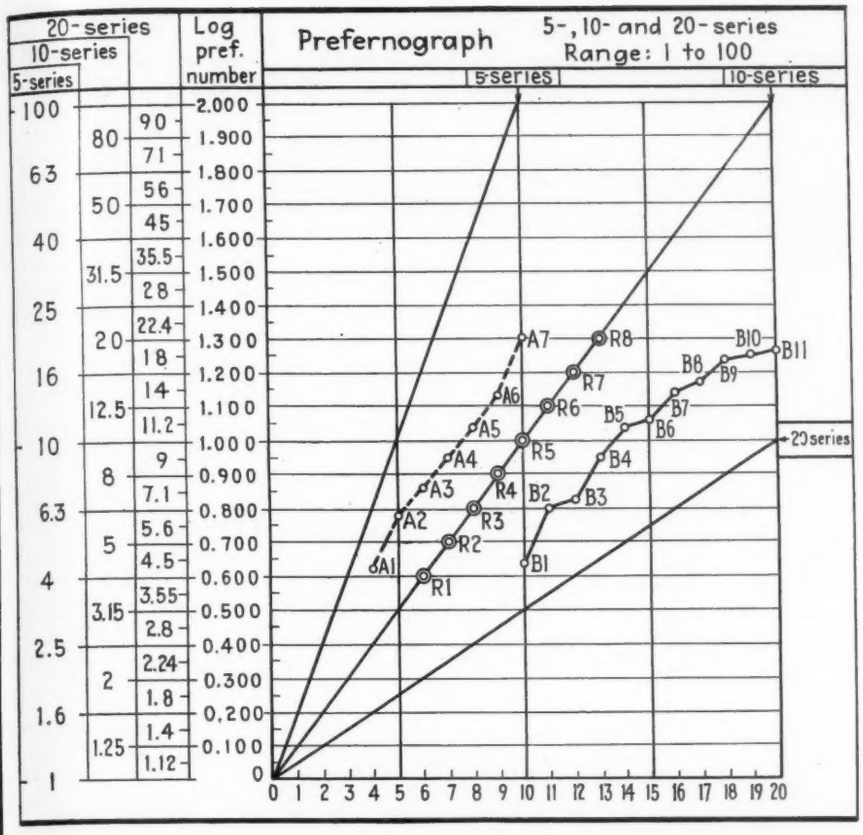


Fig. 2—This Prefernograph compares step-ups in the A- and B-series with step-ups of the 5-, 10- and 20-series of Preferred Numbers

point No. 10. Since the average steepness of the A-series is about the same as the steepness of the 10-series, this graph shows at a glance that while the values of the A-series do not conform to Preferred Numbers, their step-up is very close to that of the 10-series. The B-series has an average steepness lying between those of the 10- and the 20-series, but its step-up is very irregular. For example, the line B1-B2 runs almost parallel with the 5-series and the line B4-B5 almost parallel with the 10-series, while from B9 on, the steepness is even less than that of the 20-series. Contrasting herewith is the constant step-up of the ratings R1 to R8 of the Preferred Numbers, 10-series, range 4 to 20. It may be assumed that if the ratings had originally been laid out in accordance with the Preferred Numbers system, the values R1 to R8 would have been acceptable to manufacturers A and B. They cover the range from 4 to 20 cu. ft. by means of 8 values, instead of the 17 different ratings comprised in the combined series A and B. Series A, 7 ratings, and series B, 11 ratings, have the value 9 in common.

However, once such ratings as series A and B are commercially established, it may be uneconomic to change them, even though Preferred Numbers would give a better line-up. The practical problem is often to merge series A and B into a single "simplified" series—that is, a series whose ratings are selected exclusively from the existing series. In the present case, the Prefernograph suggests that since series A has a reasonably regular step-up, it might be acceptable as the standard series, provided the rather large gap between A6 and A7 be bridged by an additional rating, for which B9 might be selected. This would give a series of 8 ratings instead of 17 that would be better than either A or B series of ratings.

It might be objected that this decision would place manufacturer B at a disadvantage, since only one of his ratings, B9, is conserved while he has to adopt 7 new ones. Manufacturer A, on the other hand, retains all of his own ratings and has to add only a single new value. Offhand, the answer is that A has an advantage because his series is basically a better one than series B. However, this is not the final answer. In practice, consideration should be given also to the volume of production of the different units. If then, further study showed the desirability of including in the standard series some more units of the B-series, it might be decided to select B5 instead of A5 and B7 instead of A6. The standard series would then become: A1, A2, A3, A4 (same as B4), B5, B7, B9 and A7. Series A and B have been used here only as examples to show how problems of this kind may be analyzed. It is not claimed that the standard series listed here would be the best solution.

Set-Up of Prefernograph

The Prefernograph, Fig. 2, gives only the 5-, 10- and 20-series, and 20 steps on the horizontal scale. A fourth column giving the additional numbers of the 40-series can easily be added, and the range can be increased or reduced. However, the graph, Fig. 2, can be used for values above 100 or below 1 by dividing or multiplying these values by 10 or multiples of 10, so as to get values falling within the range 1 to 100. On the other hand, if the designer is dealing all the time with values lying in a given range—such as 1 to 10, or 10 to 100—, the vertical scale of the Prefernograph can be fitted to this range.

The designer can easily make a graph for the range of values and the Preferred Numbers in which he is specially interested and have this manifolded to get worksheets for use in analyzing problems. Still more convenient is a pad of printed graphs, similar to the pads of cross-section paper commonly available. A clearly legible Prefernograph form giving the 5-, 10-, 20- and 40 series in the range from 1 to 100, and 40 steps on the horizontal scale, can be printed on an 8½ by 11 in. sheet of paper.

Use of Preferred Numbers Increasing

During the last 10 years, Preferred Numbers have been used more and more by individual designers and committees engaged in developing industrial standards. Examples of their adoption in the work of the American Standards Association are the choice of the 20-series for sheet metal thicknesses, American Standard, Preferred Thicknesses for Uncoated Thin Flat Metals (Under 0.250 in.), B32.1-1941, and the establishment of classes of surface roughness, Proposed American Standard, Surface Roughness — B46. now being reviewed after a trial period of two years.

Preferred Numbers and the Prefernograph, effective tools for the standardizer at any time, are particularly valuable today with simplification and concentration of production so pressing.

Industry and Societies

NEWS · READER LETTERS · MEETINGS

Hundred-Million Volt X-Rays To Give Scientists New Tool

SCIENCE will poke its inquisitive finger into fields hitherto closed to man when the General Electric Research Laboratory completes installation of a 100,000,000-volt "induction electron accelerator."

Vastly more powerful than anything yet produced or controlled by man, this present to abstract science comes in a package hardly less imposing than the device itself, for three-foot concrete walls are needed to house the accelerator.

Capabilities of the new tool are a matter of conjecture, scientists admit, but one of the first investigations on which it will be employed will be aimed at determining the maximum thickness of armor plate or other heavy sections on which X-rays may be used for radiography. Present 1,000,000-volt industrial X-ray units are limited to steel sections eight inches thick.

Source of the accelerator's unheard-of power is a six-foot hollow glass doughnut, located in the heart of its 125-ton electromagnet. Placed between the 78-in. dia. pole faces where the magnetic field is most intense, the "doughnut" will provide a race track around which electrons will be hurled in a vacuum at Buck Rogers speeds. Actually, they will flash around the track a quarter of a million times in 1/240th sec., receiving a 400-volt push each time around. Since the electrons will travel a total of almost 800 miles, their paths will have to be guided with an accuracy which one of the designers likens to "shooting on a curve for a distance as great as that between Schenectady, N. Y., and Chicago and hitting a three-in. target."

Hardly less imposing than the accelerator's capabilities are some of its statistics. Its main part is the 125-ton electromagnet, which is being fabricated from more than 100,000 pieces of silicon steel 0.014 in. thick. These will be cemented into large slabs from which the electromagnet will be assembled. It could not be made in one piece because it will operate on alternating current.

Operation of the accelerator will be similar to that of a transformer. Its "primary" will consist of two 98-in. coils of insulated copper conductor. The "doughnut's" vacuum acts as secondary. Electrons will be speeded up during the first quarter of each cycle of alternating current, which changes 60 times a second. At the end of the quarter-cycle, the electrons will strike a target and generate a beam of highly-penetrating X-rays which will emerge from the machine along with scattered high-speed electrons. It is for protection

Looking not in the least awed by their creation, Dr. E. E. Charlton, right, and W. F. Westendorp, examine one of the 98-in. coils through which alternating current will be relayed to generate 100,000,000-volt X-rays. These men designed the induction electron accelerator whose capabilities are such that not even its creators know what it can do

against these discharges that the massive walls were built.

The accelerator, designed and constructed by Dr. Ernest E. Charlton, head of the G-E Laboratory's X-ray section, and W. F. Westendorp, is the second built by G-E. One of 20,000,000-volt capacity was completed last December with the assistance of Dr. Donald W. Kerst, of the University of Illinois, who is believed to be the first scientist to apply the principle of the accelerator successfully.

Although the induction accelerator bears superficial resemblance to the cyclotron, it is quite different. The cyclotron speeds positive particles by whirling them around in the field of a powerful direct-current magnet. They are accelerated only periodically during their course, and coast the remainder of the time. Electrons are speeded continually in the accelerator, and reach a speed approximating that of light.

Detector Eliminates Errors in Tube Production

THE WESTINGHOUSE LAMP DIVISION is using a newly-developed thorium detector to speed up production of high-power radio tubes and to prevent errors which could shorten the life of communications equipment for the armed forces.

The detector saves hours and guesswork in sorting pure tungsten and thoriated tungsten filament wire. Both of these materials are necessary for filaments in various types of tubes. They are not interchangeable, and use of the wrong wire results in rapid degeneration of the tubes.

Under the new test, samples are burned in an electric carbon arc while the observer watches through a spectroscope. If the sample is pure tungsten, two lines may be seen in the spectrum; if it is thoriated tungsten, four lines may be seen. Previously, tests were performed by dipping samples into several acids and examining the residue for thorium or by heating the wire and testing its brittleness.

Windshield Plastic Diverted to Waterproofing

PLASTICS which saw peacetime use as the binder in automobile safety glass are serving in the armed forces these days—so effectively that none can be spared for home defense.

The transition came about when war shattered the nation's automobile industry by forcing conversion of the auto plants and halting supplies of rubber. That left the chemical industry with a huge vinyl and butyral plastic production capacity for which it had no use, and without rubber for such items as raincoats and rubberized fabrics.

Several plastics manufacturers set about cancelling the shortage by means of the surplus. Monsanto Chemical Company was among the companies asked by the OCD to find a substitute for the rubber hose on stirrup pumps. Stanley Chemical Company went to work to find an acceptable plastic for waterproofed fabric. Monsanto turned up with an offshoot of its Saflex, a polyvinyl butyral, that was so good the armed forces wanted it all, leaving none for OCD. Stanley developed Haydenite, also an offshoot of safety-glass filler, which it claims is better, cheaper and easier to apply than earlier coatings.

Discussions and Comments from Readers

PENDING PATENT PROPOSALS "OUTRAGEOUS," INVENTOR SAYS

To the Editor:

With reference to bills S.2491 and S.2303 which are pending before the Senate Patents Committee, upon reviewing the contents of these bills I am amazed that they can be taken seriously even in war-time. They constitute the most outrageous attack upon our patent system that has come to my attention in my twenty years in the field of machinery design. If their purpose is to assist with the war effort, they will achieve exactly the opposite result.

Of the inventors I have met in the last two decades, including myself, it would certainly hamstring their efforts to get their inventions developed by any organization capable of the necessary engineering and financial investment.

It has been my experience in the last twenty years that even the present patent laws grant such limited patent privileges as to make it impossible to get American corporations to develop the really important inventions requiring large investments.

Passage of such bills as those now pending would beyond any shadow of doubt completely terminate such developments in this country.

—ROBERT E. BRUCKNER
Mechanical Engineer

Editor's Note—The bills referred to by Mr. Bruckner are before the Senate Patents committee which was recessed during September because of the press of other business, including the election forthcoming within the next few days. Senator Homer T. Bone, Washington Democrat, chairman of the committee, has made it clear that the committee will be recalled to finish its investigation. Senator Bone says the spectacle cartel definitely will be investigated before the inquiry is closed, along with any other topics which may be developed in the meantime. The list of subjects for further investigation was curtailed by committee vote despite Senator Bone's request that it be kept open until all hearings have been terminated. When investigations have been completed, hearings will be continued to give all interested persons a chance to testify. Thereafter, the committee will retire to executive session to consider what legislation is shall present.

SOLUTION FOR OCTOBER MARINES AND NATIVES PROBLEM

To the Editor:

The third man is black. If the first man were white, he would say so, and if he were black, he would claim to be white. Thus, when the second man answers that the first man said he was white, he is telling the truth, and is therefore white. But when the third man says the second man is black, he is lying. Therefore, the third man must be black. —H. E. SMITH

ORDNANCE EXPERTS DEFINE SMALL ARMS AND ARTILLERY

To the Editor:

In his article in the August issue of PRODUCT ENGINEERING, Lt. Colonel J. H. Frye, speaking of the substitution of steel for brass in cartridge cases, states, "Practically all sizes of artillery cases are being made from steel. . . . The steel cartridge cases . . . are quite as satisfactory as the brass ones, and production orders have already been placed with more than forty-five manufacturers."

Can you tell me what is included in the category of "artillery cases?" Does this include, for example, cases for 50 cal. machine guns and 20 mm cannon?

The projected saving due to this substitution quoted by Lt. Colonel Frye is reported at from 300,000 tons for 1943 which is about one-sixth of our annual consumption of copper. —C. F. S.
Bridgeport, Conn.

Editor's Note—In reply to C.F.S.'s question, army ordnance department

officials submitted this unofficial definition:

"The line of demarkation between small arms and artillery comes at .50 caliber. In other words, .20, .40 and .50 caliber weapons, including pistols, rifles, machine guns, etc., are classified as small arms. Anything larger, as 20mm, 40mm, 3 in. and on up to the largest (16 in. for U. S.), is classified as artillery. This classification embraces the ammunition as well as the weapons themselves.

"As for the projectiles, practically all those used with the small arms are bullets, sometimes called ball. Some of these are armor piercing. Most of the artillery projectiles are of the armor piercing and shell type, the latter containing a chamber filled with high explosive for detonation and fragmentation.

"The word 'case' designates the brass powder container which is essentially a tube closed at one end (in the center of which is located the 'primer' for igniting the powder charge) and with its open end surrounding the base of the projectile. It holds the propelling charge of smokeless powder. Case and bullet or shell together is known as a complete round of ammunition and for small arms is called a cartridge. The cases used in artillery and small arms are referred to as cartridge cases."

SIMPLIFIES SOLUTION OF STEVENS' PROBLEM

This is the third solution submitted by readers for the problem of finding the true size of the angle between two intersecting straight lines. Originally presented by Herbert H. Stevens, Jr., in an article entitled "Angles in Space," PRODUCT ENGINEERING, July (p. 392–394), the problem drew solutions, printed in last month's issue (p. 603) from William H. Rasche, of the Virginia Polytechnic Institute, and from Frederick G. Wilde, both of whose methods differed from that offered by Mr. Drew below.

To the Editor:

Mr. Stevens' method is sound and accomplishes everything that he claims but I seriously question whether he has hit upon a system that simplifies the problem. In fact, the diagrams which he finds it necessary to use are formidable. It does not seem necessary to depart from established principles and methods of geometry and trigonometry to obtain the desired information without too much trouble.

A mathematical solution for the lengths of the sides of the angle and for the angle itself in Fig. 1, p. 392. July, PRODUCT ENGINEERING, is not only simple but is exact and not subject to errors, which are inevitable in graphical solutions.

Assuming x, y and z axes in the above figure, the coordinate distances between points A and B are 2 units on the x axis, 4 units on the y axis, and 5 units on the z axis. This is all that is needed to determine the true length of the line AB. This length is simply

$$\sqrt{2^2 + 4^2 + 5^2} = \sqrt{45} = 6.71 \text{ units}$$

Simarly, the true length of the line BC is

$$\sqrt{3^2 + 1^2 + 5^2} = \sqrt{35} = 5.92 \text{ units}$$

Joining the points A and C completes a triangle. The length of the line AC is

$$\sqrt{4^2 + 1^2 + 5^2} = \sqrt{42} = 6.48 \text{ units}$$

Since these three lines of known length form a triangle, any angle may be computed from the cosine formula

$$\text{Cos A} = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\text{Cos } a = \frac{45 + 25 - 42}{2 \times 6.71 \times 5.92} = \frac{38}{79.4} = 0.478$$

$a = 61.4$ deg.

In the August article the application of Mr. Stevens' method to oblique planes has still more complicated constructions. The hopper problem can also be solved readily with the method outlined above. The true lengths of all edges can be found readily since their x, y and z coordinates are all known and the true shape of the quadralaterals M and N can be laid out on the board since each has one right angle, and values of the various angles can be computed by the cosine law as given above.

This gives all the information necessary to construct the rim around the top of the hopper. It also gives the size and shape of the walls of the hopper, and all other pertinent information.

—HAROLD W. DREW
Kueffel & Esser Company

Activities Among Technical Societies

METALS GROUP HONORS GARAND

John C. Garand, whose patient, 20-year struggle with scores of design problems tripled the fire power of the 1942 doughboy, received a special award from the American Society for Metals at its annual meeting held Oct. 12 in conjunction with the National Metal Congress, Cleveland, Ohio.

Garand, a civilian employee at the Springfield (Mass.) armory, was assigned to develop an automatic rifle. But the first World War ended before he could complete a model machine gun. He spent years on the present rifle which is rated the equivalent of three Springfields. Six distinct guns were developed, all scrapped and the best features of each consolidated into a seventh. The rear sight alone was redesigned 50 times.

The final model was hailed as the greatest advance in infantry weapons in 25 years, and it drew cheers from Gen. Douglas MacArthur, who said much of the credit for the epic stand on Bataan was due to the "fine performance, durability and firepower of the Garand rifle."

INCREASED SPOT WELDING OF AIRCRAFT UP TO DESIGNERS

Broader application of spot welding to aircraft fabrication, with resultant economies of time and money, are largely in the hands of the design engineer, according to G. S. Mikhalapov, supervisor of welding research for the War Metallurgy Committee of the National Research Council.

In a paper on "The Place and Use of Spot Welding in Design and Production of Aircraft" delivered before the Society of Automotive Engineers' National Aircraft Production meeting at Los Angeles early last month, Mikhalapov estimated that spot welding is used only on an average of 10 percent of all joints in the average aircraft. He asserted that 70 to 80 percent of all such joints could be spot welded efficiently and economically, and offered these statements in support of his contention that the aircraft industry, through its limited use of spot welding, is overlooking an opportunity to better its operation:

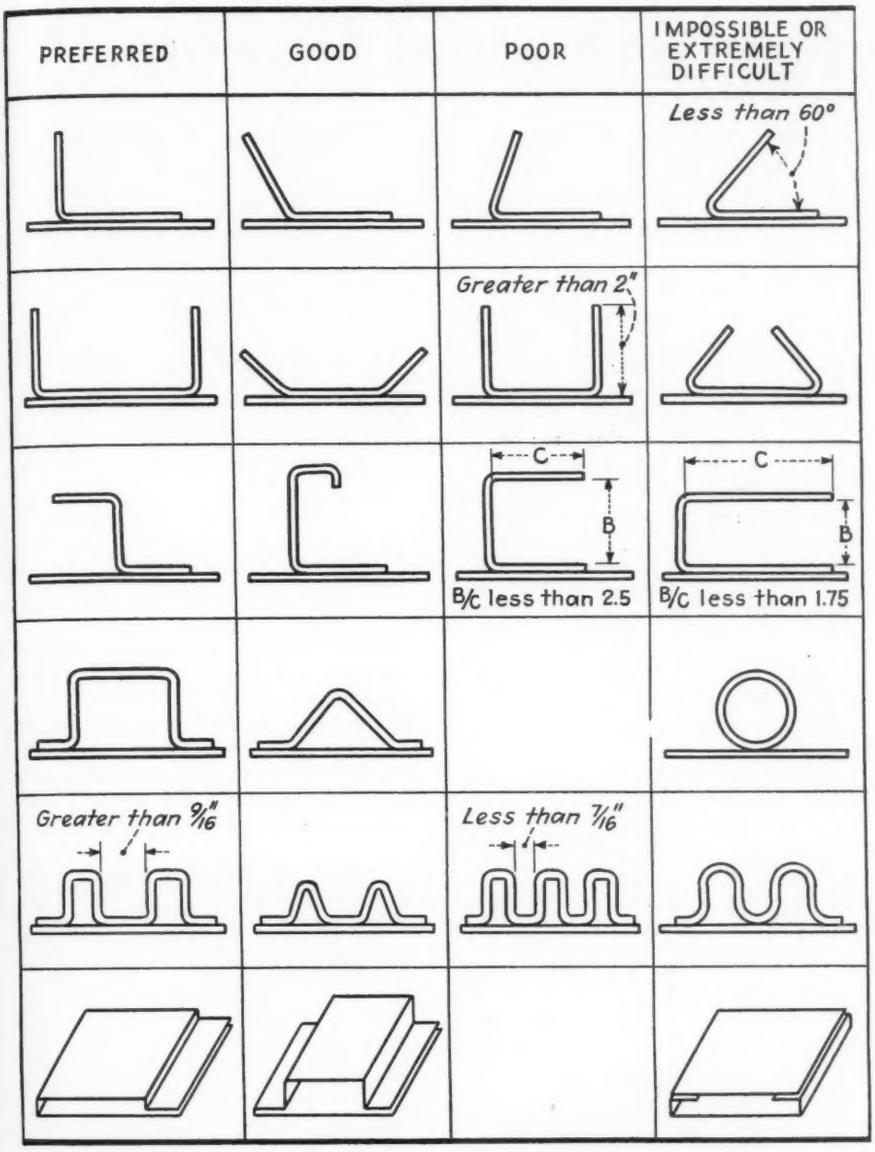
1. Wherever spot welding has been fully developed, the cost of fastening metal surfaces together, as distinguished from the cost of positioning the parts properly, has practically disappeared.

2. When spot welding installation and operation is thoroughly worked out, a considerably larger volume of airframes may be produced in a given factory space.

Mikhalapov sees the design engineer as the agent with which large-scale changeover from riveting to spot welding in aircraft production must start, and agrees that the designer has "very few reasons to give his all for spot welding." The best that can be expected of the designer, he says, is that he will not obstruct the change.

Reasons for the current disfavor in which spotwelding is held by aircraft

Spot Welding Stiffener Panels



producers include the following:

1. Designers are not particularly familiar with the process and its possibilities, and therefore specify the method they know they can depend on, i.e., riveting.

2. Currently, the primary consideration is production, not cost, and while spot welding would lend itself to increased production when it had been properly developed and installed, the time necessary for re-design, installation, worker-training, re-routing and re-scheduling of operations and establishment of the control systems necessary to insure maximum benefits makes its application questionable now.

3. No acute labor shortage has yet developed in the aircraft industry, and consequently, it is easier to erect additional factory space.

4. Certain basic conditions affecting materials, sizes, shapes and quantities must be met before spot welding may be used efficiently. Many of these call for re-design of present parts.

Spotwelding will really come into its own in the aircraft industry "as soon as the laws of economics are allowed to exert themselves," Mikhalapov predicted. He pointed out that due to the foregoing considerations, present practice is to employ those fabricating methods under which the largest output is obtained in the shortest possible time with "probably the least danger of delay." When price becomes a more important consideration than quantity, "we can look toward application of spot welding on a scale comparable to that on which it is now used in other industries."

STANDARDS BODY APPROVES 23 TESTING SPECIFICATIONS

The American Standards Association has approved 23 standards and specifications developed by the American Society for Testing Materials. Two cover malleable iron castings and cupola malleable iron, seven deal with wrought-iron and wrought-steel pipe and tubing, 12 are specifications for testing materials for boilers, pressure vessels, flanges and boltings, locomotives, etc., and two deal with fabricated steel bars and welded steel wire fabric for concrete reinforcing.

Meetings

American Institute of Chemical Engineers—Annual meeting, Cincinnati, Ohio, Nov. 16–17. Netherlands Plaza Hotel.

National Founders Association—Annual meeting, New York, N. Y., Nov. 17–19. Waldorf-Astoria Hotel.

National Chemical Exposition—Chicago, Ill., Nov. 24–29. Hotel Sherman. Victor Conquest, Chicago Section, American Chemical Society, chairman of show committee.

15th National Exposition of Power and Mechanical Engineering—New York, N. Y., Nov. 30–Dec. 4. Madison Square Garden. Charles F. Roth, manager, 480 Lexington Ave., New York, N. Y.

Air-Cargo Engineering Meeting — Chicago, Ill. Dec. 8–9. Sponsored by S.A.E. Chicago section and S.A.E. Aircraft and Aircraft Engine Activities.

Do You Know That—

IN THE MANUFACTURE of machine gun barrels, a broaching process, with two passes, now completes rifling of 20 to 40 barrels per hour whereas old rifling methods could produce but one an hour. (17)

SLIGHTLY MORE THAN HALF the electrical power required by the Ford airplane motor plant to build a Pratt and Whitney engine comes from engines just off the assembly line? In the test rooms finished motors are coupled to generators which feed into the shop service lines. (18)

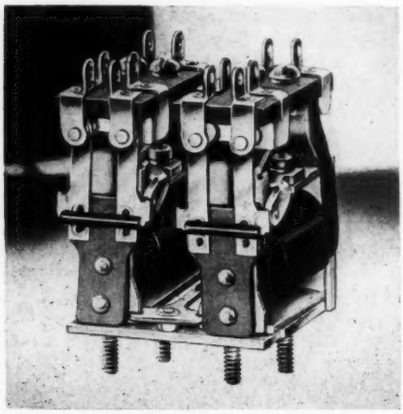
A NEW FORMULA for the phosphor in Westinghouse fluorescent lamps eliminates the use of cadmium and lead, both vital war metals, and enables a substantially higher light output? (19)

THE MILITARY SERVICES are getting demountable refrigerators whose panels are interchangeable. Products of several different manufacturers may be combined into one refrigerator, obviating interruptions caused by loss or damage to one section. (20)

New Materials and Parts

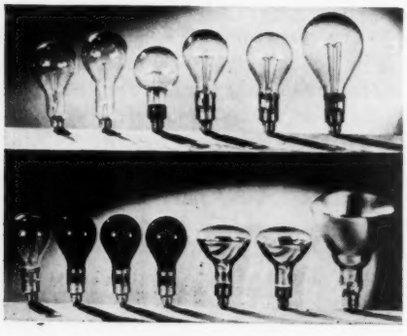
Relay Control Locks In Either Position

Feature of this new relay control device designed for aircraft applications is a mechanical lock which holds it in either position so that current need be applied to the coils only momentarily. It is non-inductive, and has a maximum rating of 5 amp. per contact. Weighing 7 oz. and with dimensions of 1⅞ x 1⅛ x 2 in., it meets Army, Navy and CAA specifications. Available for a.c. or d.c. installations. Allied Control Co., New York, N. Y.



New Infra-Red Lamps Speed Heat-Treating

Faster, cheaper and more efficient heat-treating is claimed for this new line of infra-red heat lamps designed to meet War Production Board limitations. Six clear, four ruby and three reflector types, all with tungsten M filaments, are included. Bases are reinforced with asbestos-lined mechanical straps, and reflector bulbs have built-in linings of silver sealed for protection against dimming and tarnishing. Average burning life of all bulbs is in excess of 6,000 hr. Light and compact, they save space and are easy to move around. Wabash Appliance Corp., 345 Carroll St., Brooklyn, N. Y.

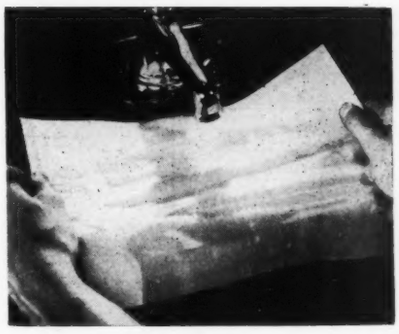


Positive-Locking Switch Ends Flash-Back Danger

Redesigned from the original heavy-duty Snap-Lock switch, the new Snap-Lock is designed to end limit switch troubles. Case is molded from dieelectric plastic, and is highly resistant to oil, dust and moisture. Heavy, wide-faced, coin-silver contacts are self-wiping on make and break actions. Contacts lock in either position and are safeguarded by spring pressure and hardened steel, cadmium-coated parts. Push mechanism is closely fitted in the housing and passes through the mechanical side only, with no chance of the operator receiving a shock from a flash-back. All parts of this 6⅛ oz. model are interchangeable. Standard assemblies are three-, two- or one-button combinations for flush mounting in a standard cavity or box-type for surface or pendant mounting. Variations on standard models may be had on specification. The National Acme Co., Cleveland, Ohio.

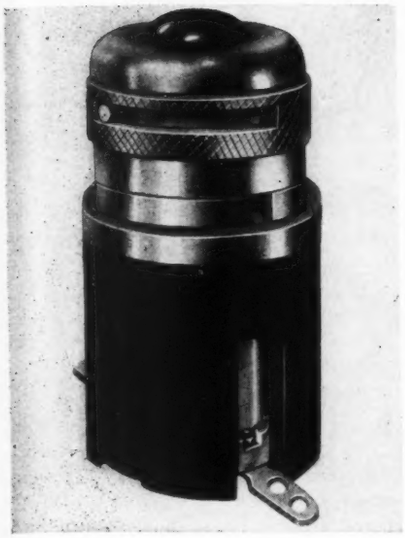
Paper Fabric Replaces Priority-Bound Materials

Aqualized paper may be substituted for cloth and burlap or other materials restricted by priorities. Individual cellulose fibers in it are interlocked to give an inherent wet strength throughout the fabric which is independent of any coating or sizing. Both water-absorbent and water-repellent types are available. The material may find such war uses as clothing, tents, sandbags and camouflage, and can be used to advantage in food packaging. Brown Co., 500 Fifth Ave., New York, N. Y.



New Lamp Simplifies Electrical Systems

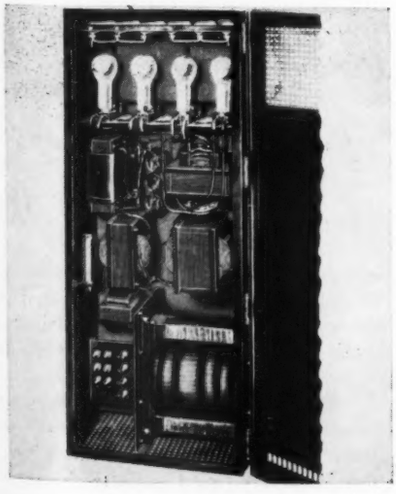
Transformers and resistors need not be incorporated in electrical systems to dim signal lights when the "Dim-E-Roid" panel and signal lamp is used. This new development uses polarized or shuttered metal disks for dimming. The device, accepted by the Army and Navy Air Corps for use in instrument panels of military aircraft, thus offers no interference with the electrical circuit.



"Dim-E-Roid" is made entirely of nonferrous metals and uses a plastic jewel of any color for differential signal purposes. Two models are available, one of which uses a shuttered metal disk which is adjustable from total blackout to full intensity. Opposing disks are contained in the head of the instrument and are easily adjustable. The other model uses opposing polarized disks and operates on the same principle. American Radio Hardware Co., Inc., 476 Broadway, New York, N. Y.

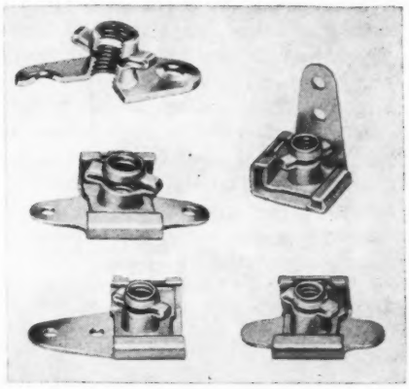
Power Rectifier Built To Special Design

This power supply operates from a.c. lines to provide continuous direct current for d.c. or battery-operated equipment. These instruments may be designed to fill special orders. Shown here is one to eliminate batteries and generators used with railroad signaling equipment. It employs gaseous, bulb rectifiers, has a two-section filter and an automatic device to regulate voltage. It delivers 110 volts, d.c. at currents up to 15 amp. Standard Transformer Corp., 1500 N. Halstead St., Chicago, Ill.



Special Bases Increase Value of Anchor Nuts

New floating anchor nuts are made of regular channel nuts in special bases which allow specific anchor-nut applications where "float" accommodation is desired. Nuts may be snapped in



and out of the new bases. Available models include floating one-lug, two-rivet nuts, floating right angle nuts and floating plain anchor nuts. Bases have regular rivet holes, dimpled and countersunk holes or are plain for welding. Nuts and bases are available in stainless or cadmium-plated steel and anodized aluminum, plain or countersunk. Any combination may be had on special order. Boots Aircraft Nut Corp., New Canaan, Conn.

New Gum Allows Stickers To Be Fastened to Metal

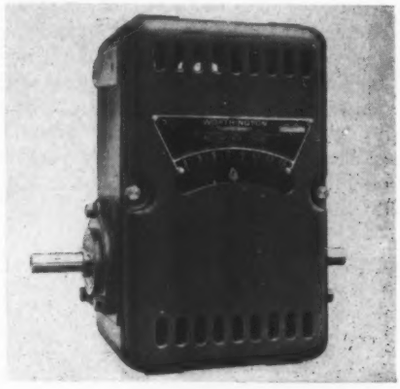
Solution of the old problem of how to make labels stick on metal surfaces is claimed for a new adhesive developed by the Ever Ready Label Corporation. The new substance may be applied either to paper or linen fabric on which inspection data, instructions or warnings may be written. Ever Ready Label Corp., 141 East 25th St., New York, N. Y.

Powdiron Compounds Save Materials, Machining Time

Powdered iron parts and bearings, made with three different formulas flexible enough to give a broad range of uses, meet the need for savings of critical materials and for reduction of machining time. Powdiron parts are made of pure metal powders, dieformed to extreme accuracy. One of the three formulas, Powdiron 55-P, is a porous iron-bearing alloy which contains no tin and only five percent copper. Available with or without impregnated lubricants, it has tested as follows: ultimate tensile strength, 12,000 lb. per sq. in.; weight, 333 lb. per cu. ft.; baby Brinell hardness, 25-40; Rockwell H hardness, 25-60; oil content by volume, 32 percent. Powdiron 59-I, straight iron containing 25 percent oil by volume, and Powdiron 61-IC, iron alloy containing no tin, 10 percent copper and 25 percent oil by volume, also are available. Bound Brook Oil-Less Bearing Co., Bound Brook, N. J.

Variable-Speed Unit

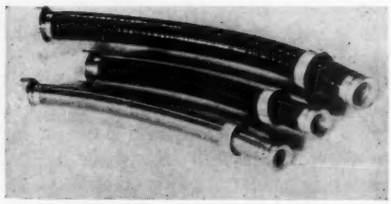
Allspeed, a new, variable-speed, multiple V-belt drive, is equipped with a mechanical, positive, belt-tensioning device which compensates automatically



for that increase in the belt-contact arc which results from increases in speed. The instrument's range is from ⅓ to ¾ hp., and its speed ratio is 16 to 1. It is ball-bearing equipped and designed to operate in any plane. It can be coupled to any standard motor and the output shaft run at motor speed. It need not be dismantled to change belts. Worthington Pump & Machinery Corp., Harrison, N. J.

Plastic Conduit Casings Save Weight and Rubber

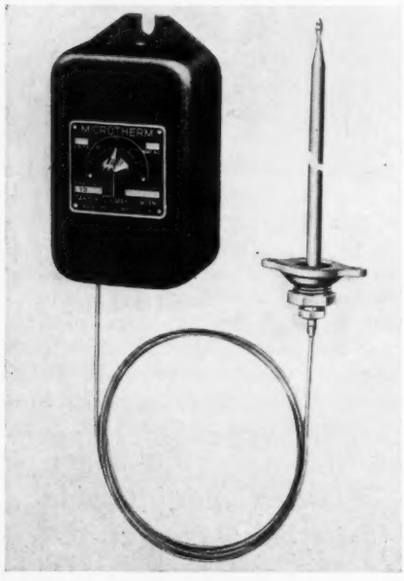
Substitution of plastic for rubber as a covering for wire conduits not only eliminated a drain on a vital commodity but also resulted in weight savings. Amerflex conduits, used principally in planes, tanks and boats, are covered with three types of plastic, each of which resists wear, heat, abrasion and most solvents, including gasoline and oil. Flexibility, toughness and resist-



ance of these plastics allows them longer life than rubber. Illustration shows bottom conduit covered with Transflex, a transparent plastic which does not become brittle at sub-zero temperatures. Middle specimen is covered with Irv-O-Lite, which has high tensile and dielectric strengths and which is available in six colors. Top specimen is covered with Hyflex, which has all the properties of Transflex and which comes in six colors also. Searle Aero Industries, Inc., Orange, Calif.

Remote Bulb Microtherm Avoids Bad Locations

This remote bulb Microtherm may be mounted in an accessible location removed from vibration, dirt and extreme temperatures where it will control temperatures in ducts, tanks, lines, dryers, liquids, cooking kettles and similar installations. Available with or without armored tubing. Barber-Colman Co., Rockford, Ill.

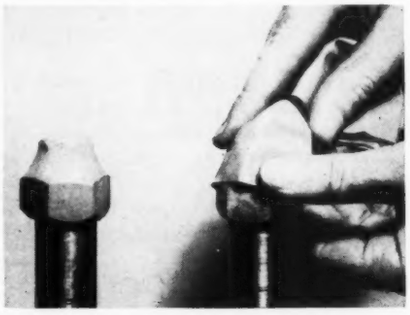


New Electrode Speeds Welding, Cut Costs

Designed for use with the "Fleet-Fillet" welding technique recently announced, "Fleetweld 11" electrodes are fast-flowing and insure deep penetration of metal into the root of the joint. The new type is of shielded-arc type and is heavily coated to exclude oxides and nitrides from the weld. Use of the new electrode and the Fleet-Fillet technique permits fillet welding to be completed in as little as half the time previously required for a given job. Cost savings of one-third to one-half are reported. The Lincoln Electric Co., Cleveland, Ohio.

Cellulose Tube Seals Defy Dirt, Rust, Sabotage

"Cel-O-Seal" seals, common on bottled goods, are being used to close pipes, tubes and lines on war goods ready for shipment. The hoods keep dirt and rust out of openings they cover, and a broken seal is evidence of tampering. Seals are bright red, and can hardly be missed during final assembly. They replace cork, rubber or metal stoppers formerly used on a large scale in aircraft assembly. Hoods are shipped in containers of liquid and placed on open pipe ends while wet.



As they dry, they shrink tight around the surface to be protected. E. I. du Pont de Nemours & Co., Wilmington, Del.

A.C. Heavy-Metal Welder Based On New Principle

This new a. c. welder, designed to increase welding efficiency and speed on thick, heavy metals, operates on a perfect electrical circuit which provides just the proper voltage for every setting. The new welder is based on a revolutionary design principle which finds the transformer and reactor built as an integral unit with the reactor coils surrounding the air gap to prevent leakage. Thus continuous control is provided from 35 to 250 amp., striking characteristics are improved and the unit size and weight are reduced. The new welder has no plugs, taps or switches, and is controlled manually at the top of the unit. Available in units up to 600 amp., this product

supplements the existing line which covers a welding range from 5 to 600 amp. Illustrated is the 200-amp. unit, smallest of the new series. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

New Adhesive Resin Tops Military Specifications

Uformite CB551 surpasses army and navy specifications for cold-setting resin adhesives. Supplied in powder form easily dispersible in water, Uformite, an urea formaldehyde waterproof resin, requires no hardeners or setting agents. It begins to set as soon as water is added. Life of the mix varies with the temperature, but Uformite is usable for four hours at 75 deg. F., the lowest temperature at which it may be applied. Tests showed the resin to have an average block shear strength of 3,100 lb. per sq. in., a dry plywood shear strength of 380 lb. per sq. in., and a wet plywood shear strength of 330 lb. per sq. in. In addition to aircraft and marine construction, Uformite is applicable to structural fabrication, furniture construction, self-retentive and clamped joints, lumber core gluing and curved construction of all kinds. The Resinous Products & Chemical Co., Inc., 222 W. Washington Square, Philadelphia, Pa.

Cotton Belting Replaces Rubber and Leather

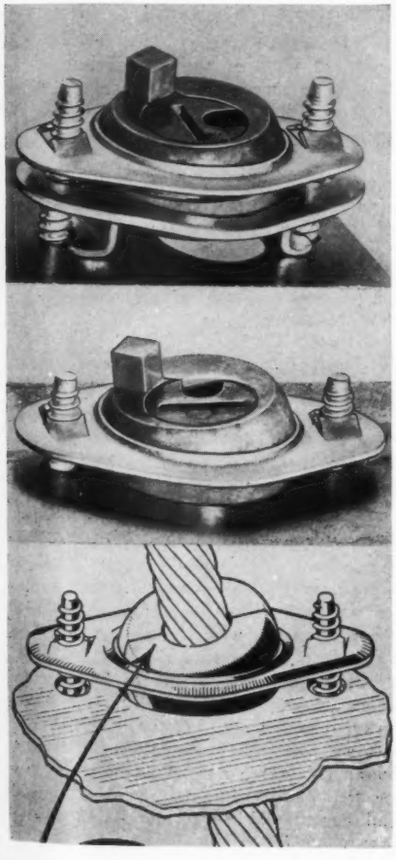
Impregnated cotton belting is available as a substitute for rubber or leather in engine mounts, shims, vibration insulators and similar uses. Finished in much the same manner as asbestos brake lining, this material is available in flexible or rigid forms with a hard or fuzzy surface. Slight variations in manufacturing processes allow extremely hard surfaces. Southern Friction Materials Co., Charlotte, N. C.

Brightening Powder Cuts Metal Loss in Pickling

Surbrite added to hydrochloric or sulphuric acid pickles produces bright, smut-free surfaces on iron and steel, reduces acid consumption and metal loss and effectively controls electroplating difficulties which follow pickling. As little as 0.2 percent by weight may be used effectively, although high temperatures and large unit areas require additional powder. Available in two formulas, "S" and "H". Hanson-Van Winkle-Munning Co., Matawan, N. J.

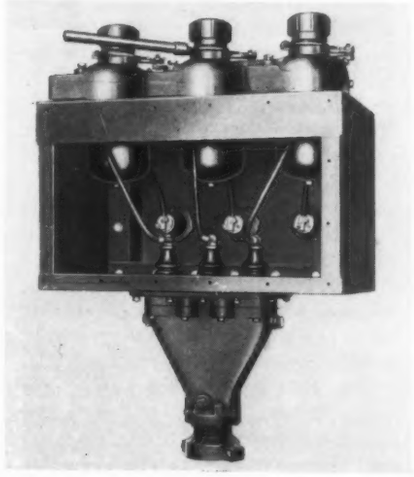
Guide Blocks Use Plastic Fittings

These three new guide blocks, through which cables may be passed at any angle, employ phenolic plastic guides. Type 1, which accommodates cables up to $\frac{3}{16}$ in. dia., are composed of three-piece guides housed in an aluminum base and a spring-steel speed nut. The eccentric center plug may be rotated to center the cable, and plastic parts may be replaced without unthreading the cable. Type 2 also for $\frac{3}{16}$ in. cables, is used where a $\frac{33}{32}$ in. hole in the structure is feasible. It dispenses with the aluminum base and houses the guide in the structure, holding it in with a speed nut. Type 3 uses a two-piece guide in which natural graphite is impregnated to make it self-lubricating. This model may be used as a control-rod bearing as well as a guide block. It is available in 15 sizes from $\frac{1}{16}$ to $\frac{1}{2}$ in. dia. Tinnerman Products, Inc., 2041 Fulton Road, Cleveland, Ohio.



New Cutout Gives Low-Cost Short-Circuit Protection

Gang-operated, oil-fuse cutouts for economical short-circuit protection and switching are adaptable for indoor or outdoor industrial use in branch circuits, single or multiple transformers, motors, control apparatus and electric heating equipment. The new device is metal-enclosed and is factory assembled with flexible, cable leads ready for connection to single or multi-conductor cables. Fuse carrier may be removed without disturbing the gang-operating mechanism. Wall or direct mountings may be had. Available with openings for conduit, cable or pothead connections in these ratings: 2,500 volts, 100-200-300 amp.; 5,000 v., 50-100 amp., and 7,500 v., 100 amp. for short-circuit protection or switching, and 2,500 v., 150-250-350 amp.; 5,000 v., 150-250 amp., and 7,500 v., 150 amp. for switching only. General Electric Co., Schenectady, N. Y.

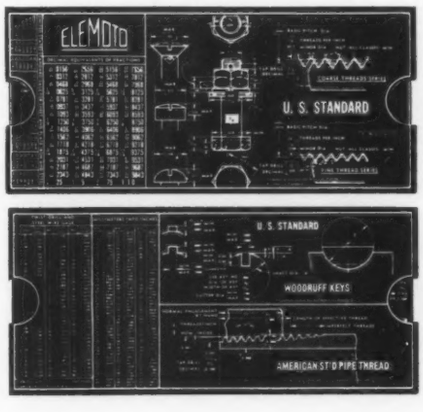


Self-Priming Pump Has Only One Moving Part

This new self-priming pump, whose only moving part is a synthetic rubber impeller, is designed for use with thick or thin coolants and is recommended for fluids which may have become contaminated with abrasives. Design is simple and pumping action is positive since the impeller fits snugly inside the housing, creating a near-vacuum and eliminating the need for priming. All parts except the impeller are of bronze, and since there are no gears, a certain amount of solid materials may move through the pump without harm. The pump is particularly adaptable to uses for which pressure requirements are low. It can be mounted at any angle and operated in either direction. Available in $\frac{1}{4}$- and $\frac{3}{4}$-in. sizes with capacities from $2\frac{1}{2}$ to 22 g.p.m. Jabsco Pump Co., Beverly Hills, Calif.

Pocket Chart Lists U.S. Standard Sizes

Elemoto slide charts speed up design and specification work and aid in training war workers. Chart contains a blueprint of American standard dimensions and data for all sizes of such elementary parts as nuts, bolts, plain and lock washers, Woodruff keys, pipe threads and tap drills. The chart carries also tabulations of decimal equivalents, sheet and plate gages, twist-drill and steel-wire gages and millimeter-inch conversion tables. Desired specifications are obtained by matching the sliding sections of the device, sliderule fashion. Elemoto Sales Co., Teaneck, N. J.



Books and Bulletins

Arc Welding Procedure

1,308 *pages*, 6x9 *in.*, 1,810 *illustrations. Semi-flexible, simulated-leather cover. Published by The Lincoln Electric Co.*, 12818 *Coit Road, Cleveland, Ohio. Price* $1.50.

The seventh edition of the "Procedure Handbook of Arc Welding Design and Practice," has been greatly enlarged in an attempt to provide all possible information which will speed up welding design and production in shops, shipyards, aircraft and ordnance plants and arsenals.

Illustrated more minutely than before is the chapter on "Typical Applications of Arc Welding." New information is given also on such subjects as welding symbols, allowable stresses, preheating, stress relief, speeds and costs, weldability of aluminum alloys, tubular construction, appearance and styling of welded design, and other subjects.

Eight sections of the bandbook cover welding methods and equipment; technique of welding (116 pages); procedures speeds and costs (119 pages); advanced experimental methods; test methods; weldability of metals (98 pages); designs for welded machines (204 pages); designs for welded structures (274 pages); and typical applications of all kinds (439 pages).

14,000 Gear Ratios

Roy M. Page—404 *pages*, 8½ x 11 *in. Published by The Industrial Press*, 148 *Lafayette St., New York, N. Y. Price* $5.

A book of tables that are helpful in the design of gear drives, this volume lists about 14,000 two-gear combinations, and from them, millions of four-gear combinations. It is divided into five sections—four sections of tables—and one giving all the formulas and 41 typical examples for solving gear ratio and speed problems.

Section 1 lists common fractional ratios and decimal equivalents, with denominators ranging from 2 to 120 inclusive. Section 2 is an inversion of Section 1, and lists decimal ratios with their corresponding logarithms and equivalent pairs of gears. Section 3, for selecting possible ratios when using 2 gears on fixed centers, lists all equivalent gear pairs and ratios in sets having the same total number of teeth. Pairs having any total number of teeth from 25 up to 239 are listed, with no single gear larger than 120 teeth. Section 4 is useful in finding gear combinations equivalent to a given fraction, and lists numbers and their equivalent gear factors. For example, for required ratio 1394/2162, the table shows practical gear sizes to be 34 x 41/46 x 37.

Technical Report Writing

Fred H. Rhodes and Herbert Fish Johnson—125 *pages*, 6 x 9 *in. Olive buckram covers. Published by McGraw-Hill Book Co.*, 330 *W. 42nd St., New York, N. Y. Price* $1.50.

An engineering investigation is not complete until a report has been written which introduces the results of the investigation into the common fund of knowledge. That, says Professor Rhodes, is where many an otherwise good engineer falls down. Hence this book.

The authors omit the subjects of business letters, book reviews, etc., and deal only with the preparation of reports on investigation work. After briefly discussing the importance, characteristics and organization of a good report, the book approaches the mechanics of its preparation, including several chapters dealing with analysis, statistics, graphical presentation, style, and correct usage of that part of the English language used by engineers. Appendices list symbols and conventions. Although many of the examples in the book are taken from the chemical engineering field, they serve to illustrate general principles of equal value to the mechanical engineer.

Machine Shop Yearbook

H. C. Town—560 *pages*, 5½ x 8½ *in. Blue clothboard covers. Published by Paul Elek Publications, Africa House, Kingsway, London, W.C.2. Price* 25s. *plus postage.*

The first edition of the "Machine Shop Yearbook" and "Production Engineers' Manual, 1942," deals with present important aspects of engineering practice. The publishers recognize a defect inherent in an engineering textbook, that it is soon out of date, and seek a solution to the problem by an annual revision which will review both established practice and the year's research and development as recorded in the transactions of technical societies and in technical publications.

Three main parts make up the book. In Part I are a few special articles by various authorities on subjects of immediate significance to machine production engineers and machine designers. A descriptive review of established British shop practice, covering such subjects as power transmission, electric and hydraulic equipment, and the various types of machine tools fills the 250 pages in Part II. The final 206 pages contain selected reprints of technical articles that have appeared in various technical journals during the preceding year. A large portion of these are taken from American publications.

The book is profusely illustrated and contains in addition about 100 pages of advertising. Its index is extremely short. Small type has been used to conserve space. Since the book is a new type of presentation in its field, the editor and publisher ask for suggestions to improve subsequent editions.

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A Photoelastic Study of Stresses in Gear Tooth Fillets

Thomas J. Dolan and Edward L. Brochamer—*University of Illinois Engineering Experiment Station Bulletin Series No.* 335. 44 *pages*, 6x9 *in. Published by the University of Illinois, Urbana, Ill. Price* 45 *cents.*

This bulletin presents the results of a study of some of the factors influencing localized stresses which occur at the fillets of several types of gear teeth, as obtained from a series of tests of photoelastic models of spur gear teeth. In order to express the results in a form familiar to the gear designer, it was decided to determine a set of stress-concentration factors from which the maximum stress at a fillet could be obtained by multiplying the nominal computed stress by the proper stress-concentration factor.

Engineering Education and the Engineering Profession

Prepared and published by the Engineers' Council for Professional Development, 29 *W. 39th St., New York, N. Y.* 15 *pages*, 6x9 *in. paper covers. Price* 10 *cents.*

The manual is published as an aid to engineers and committees acting in advisory capacities to high school students considering engineering as a vocation. It offers a general procedure for acquainting high school students with the aims and essentials of an engineering education, the aptitudes required by it and the field for engineers, both civilian and military. Material on organization and selection of local committees also is presented. A separately-bound appendix, designed for use by prospective students in supplying biographical and educational background, comes with each manual.

Plate Shear Cutting Loads Tapered Blades On Cold Mild Steel

J. P. DOOLAN
Timken Roller Bearing Company

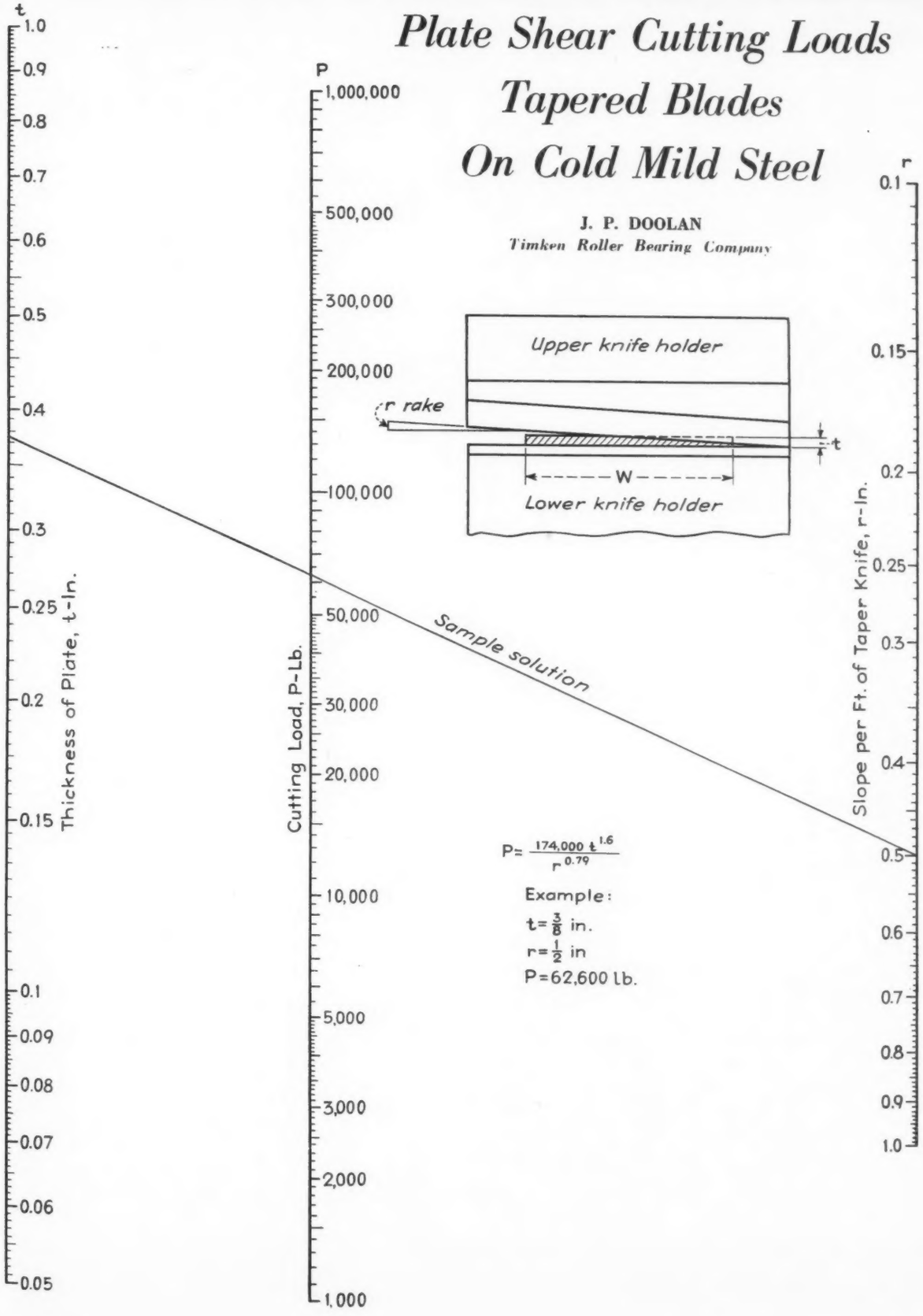
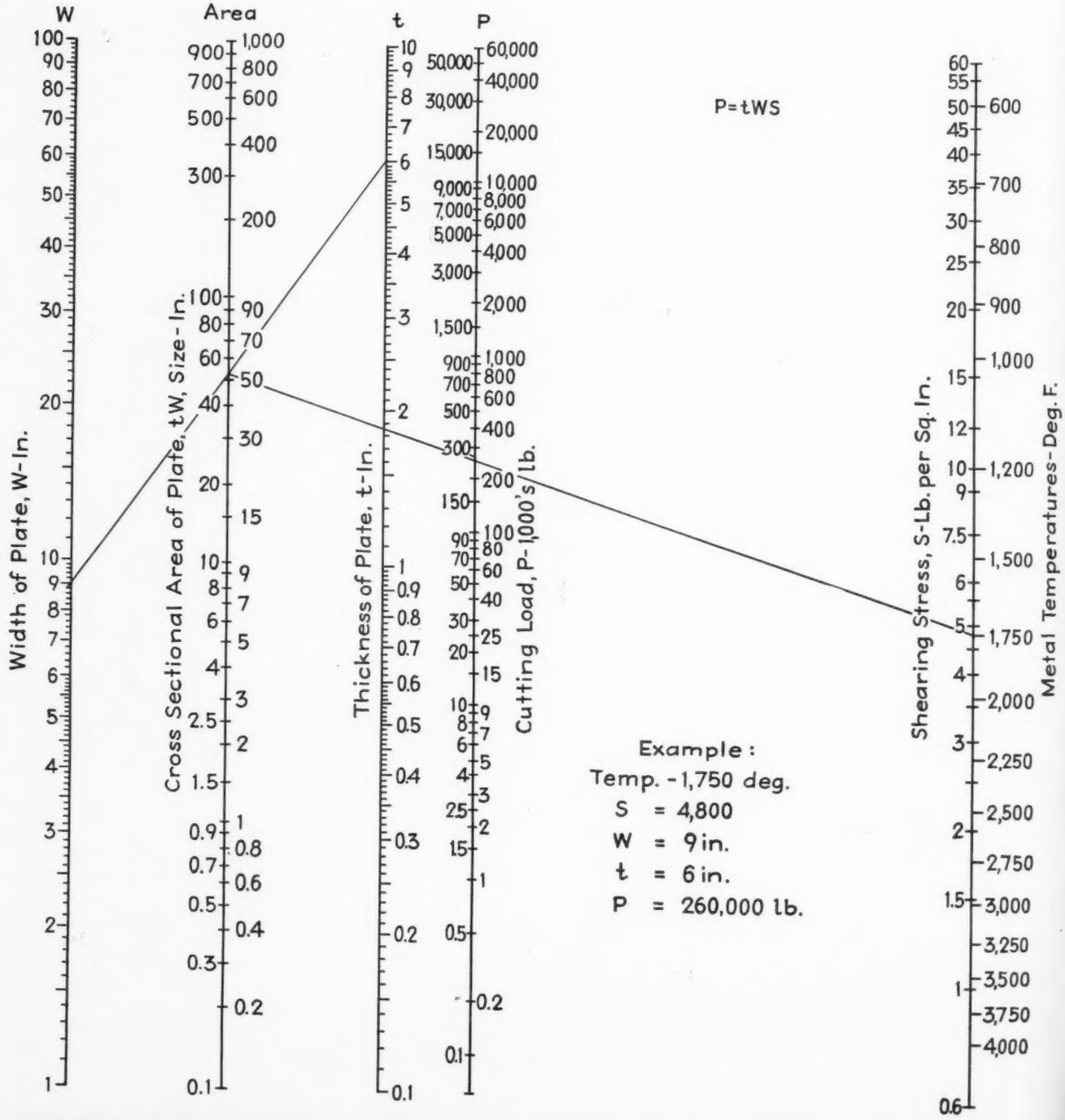


Plate Shear Cutting Loads Parallel Blades On Hot Mild Steel

J. P. DOOLAN
Timken Roller Bearing Company



PRODUCT ENGINEERING ✦ REFERENCE BOOK SHEET